# INVESTIGATION INTO SCRAPIE

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FIG. 1.—Group of Scrapie Sheep at rest.

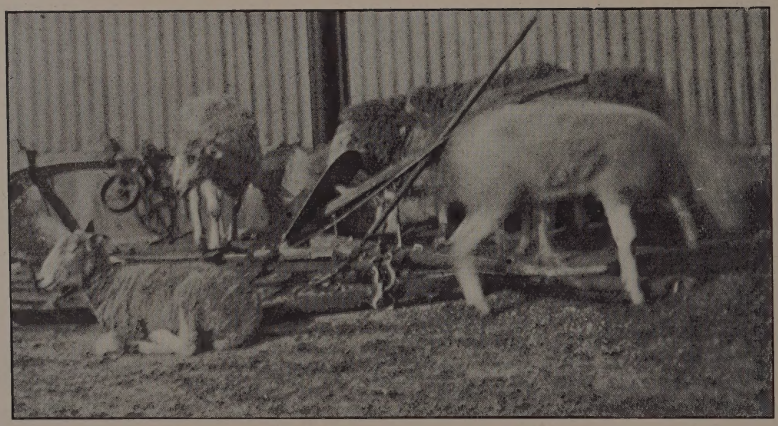

FIG. 2.—Same group a short time after. Two of them are seen rubbing themselves on the farm implements.

EDINBURGH AND EAST OF SCOTLAND
COLLEGE OF AGRICULTURE

# INVESTIGATION INTO THE DISEASE OF SHEEP CALLED "SCRAPIE"

(*TRABERKRANKHEIT; LA TRÊMBLANTE*)

With especial reference to its association with Sarcosporidiosis

BY

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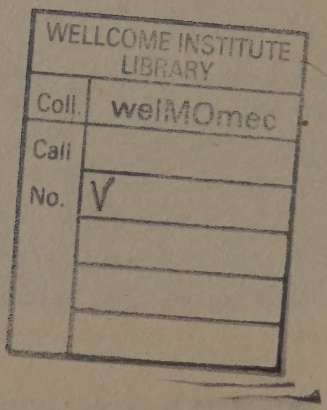
WITH AN

APPENDIX ON A CASE OF JOHNE'S DISEASE IN THE SHEEP

WILLIAM BLACKWOOD AND SONS, EDINBURGH
1914



# PREFACE.

In December 1912, Mr J. Elliot Scott, B.Sc., County Lecturer for the Border District, called the attention of the Governors of the East of Scotland College of Agriculture to the need for investigation into a mysterious sheep disease which was apparently becoming increasingly prevalent in certain parts of Roxburghshire, and which from its most striking symptom had come to be known popularly as "Scrapie." Consideration of Mr Scott's representation led the Governors to appoint a Special Committee to take such action as might seem advisable, and I was asked by them to undertake the investigation of the disease.

The Committee thereupon approached the Board of Agriculture for Scotland, which at once expressed its willingness to provide the necessary funds on condition that it was represented on the Supervising Committee. The Committee was then reconstituted as follows: From the Governors of the College—Messrs J. R. C. Smith, Chairman; Principal Bradley, Dr R. Shirra Gibb, Professor Wallace; and from the Board of Agriculture of Scotland—Messrs Barber and Wood. Mr M'Callum acted as Secretary.

Besides administering the grants made from time to time by the Board, the members of Committee have personally assisted in obtaining information regarding the occurrence of the disease, in procuring diseased animals for observation, and in other ways.

I should like to express here my thanks to the following gentlemen: Mr Elliot Scott for his assistance, rendered especially valuable by his local knowledge; to Dr Rettie for help in the routine work at the beginning of this investigation; to the Royal College of Physicians of Edinburgh for the use of the resources of its laboratory; to the Veterinary officials at

the slaughter-houses in Edinburgh and Glasgow; to the Edinburgh Lunacy Board and the Medical Superintendent at Bangour, who provided facilities for carrying out part of the investigation; and to numerous farmers, shepherds, salesmen, and others for much useful information and assistance.

I have also to express my appreciation of the help received while investigating the disease in Germany from Geh. Reg.-Rat Dr Nevermann, of the Ministry of Agriculture in Berlin; and from Dr Raebiger of the Bacteriological Institute, Halle an der Saale. The latter has allowed me to make use of his cases, and in other ways gave me great assistance. For kindness shown at this time I am also indebted to his assistant, Dr Seibold.

To prevent possible misunderstanding, it may be stated that the chapters dealing with the history of the disease in Great Britain and elsewhere were completed prior to any public discussion of this aspect of the subject. I am, however, indebted to Sir Stewart Stockman's lecture[1] for the mention of the French experiments referred to later,[2] in which healthy lambs suckled on scrapie ewes remained free from the disease.

I would like also to express my thanks to Mr Barber and Mr M'Callum for their sustained interest in the investigation, and for help in correcting the manuscript and proofs; and to Professor James Ritchie and Dr J. H. Ashworth for advice, criticism, and suggestion at all stages of the work.

[1] 'The Scottish Farmer,' vol. xxi., No. 1088, p. 1059: Glasgow, Saturday, Nov. 8, 1913.

[2] *Vide*, p. 90.

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# ILLUSTRATIONS.

# INTRODUCTION.

THE investigation to be described in the following pages deals with an outbreak of a disease among sheep, which of late years has become widely known in some of the Border counties of Scotland. That it has existed in that quarter for the last sixty or seventy years cannot be doubted, although little has been said in public about its occurrence. It is only within the last few years, owing possibly to its ravages and the consequent effect on the value of breeding stock, that the condition has been more openly discussed. Even yet, however, there is considerable reticence on the subject, a fact which militates against the acquisition of accurate data regarding the epizootiology of the disease. The formation by farmers and others of theories to explain the disease has further obscured the subject.

In order that what follows may be more readily understood, it may be well to give here some of the more important points regarding the symptomatology, &c., of the disease.

At present, so far as one can ascertain, it appears to exist mainly in Roxburghshire and Northumberland. The sheep chiefly affected appear to be the Half-breds in the first instance, next the Cheviots, and lastly the pure Border Leicesters. Instances have been noticed in other breeds less frequently, as, for example, in the South Downs. The disease seems to affect principally sheep about two years old, although it is found at other ages. The symptoms exhibited are persistent itchiness (without any evidence of "scab"); a gradual emaciation; an absence of diarrhœa; a change in gait; a weakening of muscle power; but in spite of all these, a persistence of the appetite to the end. Two varieties of the disease are believed to exist—a variety showing itchiness and a paralytic variety. The disease is, moreover, believed to be universally fatal, and to be transmitted from parent to offspring.

# CHAPTER I.

## HISTORY OF THE DISEASE IN BRITAIN.

THE disease has been definitely known in Britain under various names since before the middle of the eighteenth century. The designations applied to it include, amongst others, such terms as "Scrapie," "Scratchie," "Rubbers," "Rickets," "Goggles," "Shakings," "Shrewcroft," "Cuddie Trot." While some of these have been used at times to indicate diseases other than that with which we are dealing, it will be seen from the extracts given below that they have been mainly and, on such occasions, distinctly used to point to this condition.

One of the earliest occurrences of the disease in Britain is referred to in the 'General View of the Agriculture of Wiltshire,' published in 1811 (1),[1] and written by Thomas Davis. In his description of the disorder of sheep called the "Goggles," he says:—

> This disorder, we must observe, has tended, more than all other reasons combined, to bring the Wiltshire sheep into discredit. It is not clearly known when this disorder first made its appearance in Wiltshire, nor is it certain that it is peculiar to this kind of sheep. The symptoms are that the animal becomes loose in its backbone, with shakings in its hind-quarters, preceded by a continued drooping of the ears. It was very little noticed in Wiltshire till about twenty-five years ago, and yet it is certain that a disease which was undoubtedly the same disorder was known *in Lincolnshire about sixty years ago.* By a memorial delivered to the House of Commons in 1755 by the breeders and feeders of sheep in the county of Lincoln, it is stated that for ten years then past a disorder which they called the *rickets* or *shaking* had prevailed among their sheep; that it was communicated in the blood by the rams, and would frequently be in the blood twelve months or two years before it was perceivable, but that when once a sheep had this disorder it never recovered.
>
> The disorder called the *rickets* is now [1811] prevalent in some parts of Cambridgeshire, with the symptoms above mentioned.
>
> I am informed that all sorts of sheep are subject to this disorder,

[1] The figures in brackets refer to the lists of authorities given at the end of chapters.

though known by *various* names ; and that continuing the same breed without introducing rams from other flocks (provincially—*breeding in-and-in*) will produce it. The reason, perhaps, why this complaint has been lately known as the Wiltshire disorder, is that most of the Wiltshire wethers are sold off when lambs, and are fattened before they are two years old, and the pushing them with high keep at so early an age will most assuredly discover the *goggles* if they be in the blood. [Cf. present-day view in Roxburghshire that high feeding brings out "scrapie."]

Many thousands that have been sold, not only from Wilts but also from Hants and Dorset, have been attacked with this disorder. The sellers have been obliged to stand by the loss, and the sort of sheep has been, in consequence, brought into discredit. It has been, however, for a long time on the decline, and if care be taken in selecting the rams it will probably soon wear out. [Italics mine.—J. P. M'G.]

The points to be noted in this extract are, that although there is no reference to the symptom itching, there is a distinct reference to other characteristics of "scrapie" as one knows it now—viz., weakness in the hind legs, shakings, drooping of ears, possible heredity, lapse of two years before symptoms appear; non-recovery from the disease, "high keep" bringing out the disease, all sorts of sheep being subject to this disorder, though known by various names, and "inbreeding" producing the disease; that the "goggles" is considered to be the same as the rickets and the shakings; and that the disease was prevalent in Lincolnshire in the middle of the eighteenth century, and in Wiltshire, Cambridgeshire, Hants, and Dorset at the end of the eighteenth century.

The following extract from the 'General View of the Agriculture of the County of Cambridge,' published in 1811, p. 276, and quoted there from Vancouver's report of some years previous, shows independently the existence in the county of Cambridge of a disease with all the symptoms of "scrapie." The disease is not mentioned by name, and so far as this author is concerned, does not appear to have one. He says:—

At Ashley and Silverley are Norfolk sheep, amongst which a growing disease prevails, equally alarming with the rot (though these sheep-walks are happily free from that calamity), the first appearance of which is indicated by the wool changing to a brown [1] colour, and as the disease advances it drops off at the roots and leaves the skin quite

[1] Caused by their rubbing against earthy banks.—[J. P. M'G.]

clean and naked. At this time the animal appears extremely uneasy, constantly rubbing its head against the hurdles and fences, and scratching its back and sides with its horns, starting suddenly, running a few steps, then falling down, where it will remain a short time and then rise and begin feeding as in perfect health. The skin is perfectly free from eruption and other appearances of disease, nor are there any traces of the disorder discoverable by examination of the entrails, the body, or the head of the animal, and as no instance of a cure has occurred in any of the surrounding parishes, and, moreover, as this disorder is considered to be infectious, the sheep are usually killed on the appearance of the first symptom, though some have been known to languish under its fatal influence for ten or twelve weeks altogether.

A quotation is now given from the 'Complete Farmer' (2) of 1807 showing that the term "goggles" connoted a disease having "itchiness" as a symptom. "Goggles" is described there in the following words:—

In farriery, a disease in sheep, which is sometimes very destructive. It first shows itself, according to a writer in the Bath papers, by the ears of the sheep drooping and their *rubbing* their tails much more than other sheep. It is not supposed to have any affinity to giddiness,[1] as the sheep do not run round. It has the most resemblance to the *staggars* in lambs, but differs in this respect, that the *staggary* lambs show weakness before and fall forward, whereas *goggly* sheep show weakness behind, and when forced to run, fall backward. The sheep under the disease continue to get poorer and weaker till they cannot drag their limbs after them and ultimately die. It is supposed by some to be an affection of the paralytic kind, and that of course the seat of the disease is in the spinal marrow. It was formerly either unknown or unnoticed by farmers. No satisfactory method of cure has hitherto been proposed, but warmth and a change of pasture have been supposed useful. [Italics mine.—J. P. M'G.]

The writer in the Bath papers referred to in the extract just given is a "gentleman in Wiltshire" who wrote in 1778 (3), and the author of the article in the 'Complete Farmer' has obviously obtained his information from the Bath papers, but he has not quoted all the important points. It would be well, therefore, to give these additional points as follows:—

Within these few years we have had a disease among the sheep now generally known by the name of *goggles*, a disease which has

[1] *Goggles*, by some authors at a later period, is used as synonymous with "sturdy" or "giddiness"—*e.g.*, Youatt, 1837, page 377 of his book on sheep, and Spooner, 1874, page 194 of his book on sheep. There is a similar confusion of this disease with "sturdy" or "staggers" by French writers on sheep.—[J. P. M'G.]

destroyed some in every flock round this County [Wiltshire] and made great havoc in many. The sheep most subject to it are *two teeth.* It is not infectious, but hereditary, and undoubtedly runs in the blood. . . . I have examined a few, and found the viscera all sound. I have blooded one and found no inflammatory crust. I can neither myself imagine nor find one who can venture even to conjecture the cause. [Italics mine.—J. P. M'G.]

From the two last quotations it will be seen, amongst other things, that the "goggly" sheep suffered from "itchiness," that they had paresis of their muscles, especially of the hind-quarters; that the "goggly" sheep were clearly differentiated from "sturdy" sheep; that the disease was causing great havoc in Wiltshire about 1770; that the *two teeth* sheep were most subject to it; and that the disease was believed to be hereditary.

The following, from a communication in the Bath Papers (4) on the Wiltshire breed, again emphasises the presence of the disease in that county, and also incidentally indicates a method of prevention: "This breed is liable to a disorder called the *goggles*, which sometimes occasions very heavy losses. The only method of prevention is entirely changing the flock once in eight or ten years."

Claridge (5), writing in the Bath Papers in 1795 about Dorsetshire, incidentally shows the presence of the disease in that county, and emphasises the itchy nature of the "goggles." He says:—

> It is incumbent on me to take notice of a disorder peculiar to sheep which is sometimes fatally experienced in this county, called the *goggles:* it attacks them at all ages, and no remedy is at present known for it. The first symptom is a violent itching, which is very soon succeeded by a dizziness in the head, staggering, and a weakness in the back as if the spinal marrow was affected, under which they sometimes languish a few weeks. This disorder has been known to be fatal to the greatest part of a flock, and is considered as the most calamitous circumstance the sheep owners have to dread. It is very difficult to assign the cause of this disorder, but some of the old-fashioned farmers think that as no such disease existed prior to the introduction of the breed from other counties, consequently its origin may be imputed to this cause.

In a footnote to this paper the editor of the Bath papers says:—

> The subject is important in proportion to the destruction made in flocks by this disease, even were it peculiar to the county of

Dorset; but the idea of its being introduced [from other counties] by mixture implies the existence of the disease elsewhere: and indeed it is a fact too generally known by experience. Particular districts and races of sheep and at particular seasons may be more subject to it than others, but it is a disorder incident to the animal. That it has been so little treated on in our best publications on agriculture is a matter of surprise.

From this footnote of the editor one gathers that the disease was probably widespread, and that there was a tendency even then to say little about it.

In the 'General View of the Agriculture of Dorsetshire' in 1815 (6) there is this further reference to the presence of the "goggles" in that county:—

The *goggles* have been very fatal to the sheep in this county, but it is believed this disorder is not so prevalent as was the case some years ago. Mr Balson of Athelhamptom has suffered much in his Dorset flock by this malady, and is now exchanging them for South Downs principally for that reason. The disorder is believed to be infectious or hereditary, and a medical gentleman attempted in vain to discover the cause. The sheep when affected with this disease rub themselves very much and reel about as if intoxicated. No cure has been discovered for this singular malady except changing the flock be deemed a remedy.

In this extract the most important point, apart from showing the presence of the disease in Dorsetshire in 1815, and the emphasising of the itchy condition in "goggles," is the hint that the disease may be got rid off by changing the stock. This author states further (p. 417) that "Mr Bridge of Winford believes the *goggles* is an hereditary disorder, but it is not very prevalent at this time [1815]."

That the "goggles" was present in Hampshire in 1810 is seen from the following extract from the 'General View of the Agriculture of Hampshire' (7):—

The *goggles* is a disease sometimes but by no means generally complained of: it is so well known as not to require a particular description in this place. The means of its prevention is, in the opinion of many flockmasters and shepherds, to change the rams as frequently as possible.

And in Devonshire and Somerset in 1808 from the following (8):—

The *goggles* is a disease sometimes though rarely experienced on

the confines of Somerset and Devon. Its symptoms are discoverable in the morning when the animal first rises from the ground by an evident weakness and difficulty in raising its hind-quarters. . . . This continues for some time, getting worse and worse until the animal can move its hind parts no more. It then lies prostrate on the ground, but looking constantly backwards and making continual efforts to reach back and bite and nab the wool towards the loin, where there is evidently seated a most excruciating pain.

In the 'General View of the Agriculture of Somersetshire' (9) there is this reference to the disease existing there at an earlier date—1798: "The *goggles* or *rickets* is a disorder not much known. It attacks sheep between one and two years, and no method of cure has yet been discovered." In 'Some Farming Notes in Essex, Kent, and Sussex,' Arthur Young, in 1793 (10), makes the following statement: "Hampshires are very subject to the *rickets* (called here the *goggles*, a distemper never known with the South Downs). *Quere* this? for it is very curious."

In the last two quotations it will be noticed that "goggles" has been used as synonymous with "rickets," and Willich (11), 1802, gives the following definition of "rickets":—

*Rickets* in sheep is a disorder which occurs chiefly in the county of Huntingdon, where it is by some farmers supposed to have been introduced from Holland. This malady is one of the most fatal that can happen in a flock, for, as its causes have never been clearly ascertained, all the remedies hitherto employed for its removal have uniformly failed of success. The first symptom that indicates the presence of the *rickets* is a species of giddiness, in consequence of which the sheep appear unusually wild and ferocious, starting up suddenly and running to a considerable distance on the approach of any person as if it were pursued by dogs. In the second period, the chief characteristic is a violent inflammatory itching of the skin: the animal rubs itself furiously against trees, hedges, and the like, so as to pull off the wool and even to tear away the flesh. No critical discharge or cutaneous eruption takes place, and every circumstance indicates the most violent fever. The last stage of this malady is the progress towards dissolution, which at length follows, and the animal after having reeled about, lain down, and occasionally eaten a little, falls a victim to a general consumption. The *rickets* appear in the spring, and are hereditary: thus after remaining latent for one or two generations they break forth with increased violence, and as they appear suddenly the utmost precaution of the most judicious graziers cannot detect the malady, so that no other choice remains but immediately to cease breeding from the infected flock.

The resemblance of the disease here described to "goggles," and incidentally to "scrapie," is evident. Comber (12), in a pamphlet addressed to Dr Hunter, physician in York, in 1772, discusses the disease "rickets" as follows:—

A short description of the three principal stages, given by Mr Thomas Beal, farmer in my parish of Morboune. "The principal symptom of the first stage of this distemper is a kind of high headedness. The affected sheep appear much wilder than usual. He bounces up suddenly from his laire and runs to a distance as though he were pursued by dogs. In the second stage the principal symptom of the sheep is his rubbing himself against trees, posts, &c., with such fury as to pull off his wool and tear away his flesh. The distressed animal has now a violent itching of the skin, . . . but it does not appear that there is ever any cutaneous eruption or salutary critical discharge. The third and last stage, . . . the poor animal appears stupid, separates from the flock, walks irregularly (whence *rickets*), generally lies, and eats little. These symptoms increase in degree till death follows a general consumption, which appears upon dissection of the carcase, the juices or even solids having suffered a general dissolution insomuch that the solids have no longer any of the good properties of flesh, nor the blood of its usual colour, &c., . . . not any precise time from first symptom to death, . . . not one sex attacked more than the other, nor lean rather than fat, nor gelt sheep rather than breeding ones."

"A distemper exactly the same as *rickets* in sheep . . . among deer in some parks (particularly in that of —— Appoice, Esq., at Washingley in this county)."

"I do not find that this distemper is infectious, but hereditary equally from sire and dam; and may be latent one generation and reappear. . . . A sheep once attacked never recovers; escaping it in early years, never takes it."

"The disease was about forty[1] years standing in England; came from Lincolnshire hither (Hants), and yet I have never heard of the distemper in our county (Yorkshire)."

Mitchell (13), in his book on agriculture in 1828, deals briefly with the question of "rickets" on the following terms: "Rickets, rubbers, and shaking are nondescripts, or a distinction without much difference from black water in symptoms and cure." This does not give one much information, but it shows that these three terms were regarded as synonymous.

The mention of "rubbers" leads to the consideration of

[1] This puts the date of the first recognition of the disease in England as far back as 1732.—[J. P. M'G.]

the condition under this name. Willich (14) (1802) describes the condition in the following terms:—

> The *rubs* or *rubbers* may be known by the restlessness of the animals which rub themselves in every attitude: their skins being perfectly clean without any trace of scab: when dead their flesh assumes a greenish cast but does not possess a bad taste: sheep fed in fine meadows are more liable to be thus affected than such as are pastured on poor soils; the disease generally terminates at the end of three or four months. No cause has as yet been assigned for the rubs: the malady having hitherto appeared chiefly in the county of Norfolk.

Young (15), in 1800, describes this condition as follows:—

> I also lost from forty to fifty ewes by a complaint which has been for some years fatal in this neighbourhood, and called by the shepherds the "rubs" or the "rubbers" from their seeming to rub themselves to death, by which some very capital flocks of Norfolks in the vicinity of Bury have lost several hundreds. The following is a description given by a shepherd who seemed to have attended more than others to the symptoms: the sheep rub themselves in all attitudes—they have clear skins without the least sign of scab—never observed that it was catching—the better the food the worse they become—some few are taken as if mad, jumping or staggering about as if drunk, and they are wasted away and die in three or four months; the flesh is then quite green and not stinking. The staggering would make one suspect the *goggles* of the west, but the other circumstances vary from the account I have seen of that malady.

We have seen above that the symptoms of "goggles" are those just described for the "rubbers" by Young. Yet he thinks that the two conditions are different. His idea of "goggles" must therefore have been very different from those which we know to have been held by most people at that time (*vide supra*).

In the 'General View of the Agriculture of Lincolnshire' (16) the disease is described as follows: "The rubbers: a sort of itch. They rub themselves to death. No cure." It is interesting to note that the "rubbers" is one of the names by which the condition is known to-day in Roxburgh.

One cannot help feeling, when reading over the literature on this condition, that in the early decades of the nineteenth century and previous to that, disease conditions were much more clearly defined among sheep than they were later about the middle of the nineteenth century. It is only by extrinsic

knowledge that one can, for instance, see that Youatt (17) (1837), in his description of the "scab," is really describing two diseases. He says:—

> Among the diseases of the skin in British sheep the scab stands foremost in frequency of occurrence and mischief to the wool, the flesh, and the general constitution of the animal. The same disease, or one much resembling it [note the indefiniteness of this and the following], has been known in some parts of the world from time immemorial. It assumes different forms in different seasons and on different animals, and there are several varieties of it. A sheep is occasionally observed to scratch himself in the most furious manner and with scarcely a moment's intermission. He rubs himself against every projecting part of the hedge, against every post, and the wool comes off from him in considerable flakes. When he is caught there is no appearance whatever of cutaneous disease.

Youatt appears to be quoting entirely from Young's paper mentioned above, and not to have had any personal experience of the disease. This may explain the want of definiteness in his terminology, and the same lack of experience in the disease would appear to show why Cleeve (18) (in 1840) classed "goggles" with "sturdy." He evidently has, however, some hesitation in making such a classification, for in a footnote he says, after having given Vancouver's description of the "goggles" (in 'Survey of Devonshire' (see above, 7)):—

> Should I have been mistaken in classing *goggles* and *turnsick* under one head, I think the term *goggles* must be misapplied, and those provincial terms are very confounding. What Vancouver has described appears to me to be a paralytic affection. I recollect the complaint but never heard it named the *goggles*, the term *shrewcroft* being commonly used to designate the disease.

This quotation is from a prize essay in 1840 entitled 'Practical Essay on the Diseases of Sheep,' and yet this is all the reference that is made to the disease known and feared at the beginning of the century as "goggles," "rubbers," "rickets," &c. Taking into account, therefore, the practical silence of Youatt and Cleeve on the condition, it follows that the disease could not have been very prevalent, and yet (showing the perplexing nature of the subject) we have the following in a footnote to Cleeve's article (p. 297) by W. Humfrey of Boxford, Berkshire:—

> The *goggles* is a disease of quite a different character [from *sturdy*].

The first symptoms of it are the following: the animal begins rubbing the wool round the tail, not turning round, as the giddy sheep does, but stumbling along in a straight direction; and as the disease increases the animal staggers a short distance, then falls down, sometimes on its head, at other times on its side, rolling quite over. In the last stage the teeth turn quite black and the sheep then soon die. I am of opinion that this disease is infectious. I once knew a flock of 200 sheep, 64 of which died goggly.

Cleeve, by the way, classifies "scab" as synonymous with "rubbers"; and Spooner, in his book in 1874 (19), has no mention of "rubbers," "rickets," or "shakings."

We turn now to the question of the term "shaking" being used to designate the disease. This is one of the names used by the French for the condition—*la tremblante*,—the other name being *Prurigo lombaire;* and the word "shaking" is actually used synonymously with "rickets" for the disease in the memorial mentioned above as being delivered to the House of Commons in 1755 by the breeders of sheep in Lincolnshire.

So far, one has been dealing with the disease under its various names in England, and mostly in the south-west of England. Is there any evidence that the disease existed in Scotland at any time? Statistical accounts, books on agriculture, reports to Sir John Sinclair of the agricultural condition of the various counties of Scotland, special articles on sheep disease in various journals, have been searched, and no reference to the disease as existing in Scotland at any time has been found. And it has to be specially mentioned that in Douglas's 'General View of the Agriculture of Roxburgh and Selkirk,' published in 1813, there is no mention of "scrapie" or a disease like it. There are, however, people alive to-day in Roxburghshire who say that the disease was well known on certain farms in Northumberland and Roxburghshire sixty years ago,[1] and I know for certain that it was present there forty years ago, having been told so by the farmer on whose farm it occurred. It may be noted in passing that at the present day in Roxburghshire the disease is known by such further names as "Scratchie" and "Cuddie Trot."

To sum up the main points in this chapter, one may say that

[1] *Vide* Lecture to Northumberland Shepherds' Society at Ancroft, Northumberland, in February 1913, by John Cameron, V.S., Berwick, and published in 'Berwickshire News,' February 18, 1913, p. 6.

there is evidence that the disease has existed in Britain since before the middle of the eighteenth century under such names as "scrapie," "scratchie," "rubbers," "rickets," "goggles," "shakings," "shrew-croft," and "cuddie trot"; that it appears to have been more prevalent or more openly talked about during the latter half of the eighteenth century than it was during the nineteenth century, except towards the end when it appeared in Roxburghshire. The symptoms of the disease in those early days are exactly what one finds now in "scrapie" —namely, itchiness, emaciation, paresis, and tremblings. The absence of cutaneous eruption is noted; views are expressed as to the disease not being contagious but hereditary (? congenitally infectious). It is stated that the disease is brought in by the rams; that it affects two-year-old sheep; is always fatal; and is brought out by good feeding. Such points as these, as will be seen later, are constantly occurring in the description, by farmers and shepherds, of the disease as it exists in Roxburgh at the present day.

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(9) Do. Do. Somersetshire. London, 1798. p. 147.
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(13) Mitchell. Agriculture. London, 1828.
(14) Willich, *op. cit.* Vol. IV. p. 59.
(15) Annals of Agriculture. 1800. Vol. XXXIV. p. 418.
(16) General View of Agriculture of Lincolnshire. London, 1808. p. 372.
(17) Youatt. Sheep. 1837. p. 536.
(18) Cleeve. Journal of the Royal Agricultural Society of England. 1840. Vol. I. p. 296.
(19) Spooner. The Sheep. 1874.

# CHAPTER II.

## THE DISEASE AS IT OCCURS IN OTHER COUNTRIES OF EUROPE, AND ESPECIALLY IN GERMANY AND FRANCE.

With the exception of a reference to the occurrence of the disease in Spain in 1750, Germany, Austria, and France, so far as I can find, are the only countries which are mentioned in the literature as having the disease. No doubt the sheep of other countries are affected with it; but so far I can find no mention of it in any books to which I have had access.

The disease is known in Germany as the *Traberkrankheit* (trotting disease); *Gnubberkrankheit* (nibbling disease); *Reiberkrankheit* (rubbing disease); *Wetzkrankheit* (whetting disease); *Zitterkrankheit* (trembling disease); and *Schruckigsein* (shrugging). In France it is known by such names as *la tremblante* (trembling) and *Prurigo lombaire* (lumbar itch), as well as by other names which will be mentioned later.

One of the first references to the disease in Germany is by Fink (1) at the end of the eighteenth century. Curiously enough, it occurs in English, and is an answer to queries put to him by the Board of Agriculture of England concerning the breeding of sheep in Upper Saxony. He says:—

> There is another distemper to which our sheep are liable and which is also propagated from one generation to another. It consists in this, that the sheep afflicted with it has got a stiff hinder leg, and reels in moving forward as if its back were broken. In this state it usually bites its own hinder legs, and tears off from them the hair, together with the skin. Its strength abates, its flesh becomes from time to time more meagre, till at last it cannot any longer keep up with the rest of the flock, and, remaining behind, falls on the ground and perishes. The cause of this disease seems to be a gouty matter. I had once bought some rams which belonged to a breed where this disease had gained great influence. Knowing nothing about this circumstance, I put those rams to my ewes without any apprehension

of danger; but ere long I got acquainted not only with the name but also with the nature of this dangerous distemper. Soon after this accident it happened, I know not how, that some rams of my flock got admittance into the flocks of a farmer, and it was observable in a little time that they had introduced into these flocks the same disease, with all its fatal consequences, though it was before that time never known in that farm. To rescue my sheep from so destructive an enemy, I tried after some years to incorporate with my flocks sound and strong rams taken from a herd perfectly free from the disease, and I am happy to say that by this means the evil gradually diminished so as to leave no trace behind it. The same remedy was also applied by other farmers, and their flocks were likewise restored to health.

After the above letter appeared, the disease was much studied by farmers and others in Germany, and the fruits of such study are collected and most easily obtained in the excellent article on the subject in 'Die innern und äusseren Krankheiten des Schafes,' by Dr Georg May (2), published at Breslau in 1868. It is such a comprehensive article, and such an important one, that no apology is necessary for giving here a translation of practically the whole article. It is as follows:—

The "trotting disease" is a chronic disease, more frequent in the Merino sheep and their cross-breeds than in the coarse-wooled races. It attacks animals from one to three years old, is hereditary, becomes rooted in and makes havoc of the flocks, from which it is very difficult to eradicate.

### Symptoms and Course of the Disease.

*Preliminary Symptoms.*—Preliminary symptoms, though not always present, are yet frequently found. From four to six weeks and even longer, before the actual unmistakable outbreak of the disease, the animals get a peculiar fixed look. At times they set their ears alternately, and then let them hang limp. The ears begin to tremble whenever the sun shines with any strength upon the sheep; and here and there the animals take to gnawing their legs and tails. Their behaviour is also awkward, and their gait now and then unsteady, while in walking they often raise their nose.

At the actual commencement of the disease the sheep are shy, timid, easily frightened, a condition usually called "shrugginess." They have not the vigour of perfectly healthy animals, and let head and ears droop. They tremble frequently, and are not fond of running. They are pensive and inattentive. The rams butt less often than was their wont, and when they do their weakness is apparent, as they frequently sink to the ground on their hind-quarters. Their walk becomes uncertain, stiff, and tottering, with their hind legs far apart. They cannot gallop, and in enforced quick movements their step is a short trot, giving rise to the word "trotter." When they do have to

move quickly they fall, and it is very difficult for them to rise again. If an animal of this order is raised, and held so that the left arm passes securely round its breast, the right hand catching the right hind foot, thus bending the lumbar vertebræ, it is found that the animal soon begins to make repeated nodding movements with its head, a thing never seen in a healthy sheep. If the sheep is then let go, and the animal tries to get on its feet, its legs will either bend under it or it will collapse altogether in a more advanced stage of the disease. It is also difficult for such sheep to step over high door-sills without sinking down or falling. In standing they often turn and look at their bodies, especially at their sacral region. Along with this is, in most cases, a feeling of itching, particularly in the lumbo-sacral region and the legs, so that the animals keep rubbing and gnawing at themselves. From this circumstance are derived the terms "whetters" and "gnawers" to designate such animals. The wool grows pale and uneven. The skin on examination is found in some places unchanged; in others, irritated from rubbing, and in some individual cases, with diseased knotty swellings. Richthofen said long ago that he had found thick spots, either yellow or whitish, on parts of the skin from which the wool had been rubbed off. Later on the skin becomes peculiarly dry, and either scaly or scabby. Funke maintains that, on being touched, it reddens more easily than the skins of healthy animals, and that then vessels filled with blood are distinctly visible in it. At the start neither the digestion nor the nourishment of the animal suffers: nor is the pulse altered. Later on, however, deficient feeding, decrease of desire for food, slower rumination, and less frequent evacuation of the bowels set in. The ears hang more limp than ever, and the gaze becomes more exhausted and vacant. As the disease proceeds, the timidity of the sheep increases; the weakness in the sacral region grows to an intense shaking, giving rise to the name "lumbarshaker." The voice becomes changed, bleating becomes less frequent and more hoarse, till eventually it becomes a growl. Gradually, through want of appetite and disturbance of digestion, emaciation becomes very evident. The wool all over the body, as also the skin, becomes dry and pale. The animals lie a great deal, rise from the ground with the greatest difficulty, and fall down easily. In some animals, great muscular weakness is soon perceptible, owing to which their knees often give way under them, and they have great difficulty in rising, a condition which has been erroneously looked upon as a kind of epilepsy. Such sheep often crawl along on their abdomen without being able almost to use their legs at all, whereby defæcation and discharge of urine become almost mechanical.

Along with very pronounced weakness and an unmistakable setting in of hectic fever, the diseased sheep become wasted to skeletons, and sooner or later offensive fluids cause a complication first recognised in a general sinking of the temperature. This is accompanied by a discharge of foul mucus from mouth and nose. The conjunctiva of the eyes becomes strikingly pale and produces an abnormal secretion. The animals can scarcely raise themselves from the ground; they grind their teeth; vomit occasionally; and gnaw at themselves

violently and without ceasing, till ultimately death accompanied by signs resembling paralysis or by the beginning of convulsions terminates the sad scene.

In recent years an attempt has again been made to do what Störig and Michaelis did at a much earlier period, namely, to classify the malady in question into two diseases, the "Trotter" and the "Nibbler."[1] The former of these two diseases ("the trotter") lacking the gnawing phenomena is said to be the less dangerous. This division is, however, not admissible, as in both cases the essential nature of the disease is exactly the same—one symptom being more pronounced in one case, and the other symptom in another case. Both conditions may possibly occur in separate individuals in one flock, but just as often, or even oftener, they appear together in the same individual, although A. Thair, in his article on Rudolphi's publication in the 'Möglin Annals' (vol. xii. p. 56), remarks that, curiously enough, he had never seen the "trotter" and the "gnawer" appear together in his district.

*Duration of the Disease.*—As a rule, no regularity is observable in connection with the "trotting" disease. Its duration varies according to the stage of the disease, according to the individuality of the animals attacked, and also according to the season of the year. It must be stated at the outset, however, that as regards duration, on the whole, great differences are evident according to which of the two forms of the disease has seized on the animal, as Elsner has already pointed out in his handbook on sheep-breeding. In single, usually the rarer, cases the disease sets in with startling rapidity, the symptoms increase apace, and in a few days death takes place. In general, however, it lasts from six to ten or twelve weeks and even longer. The "gnawer," as repeated observation has shown, often terminates earlier than the "trotter." From an observation made over and over again, it is seen that the disease is of shorter duration in summer than in autumn and winter, and that younger animals succumb to it sooner than older.

There exists, however, another course of the disease which is rather disguised and obscure, as in single animals suspicious signs of the disease may be very slight for a long time, even years perhaps, before the evil unmistakably breaks out. Animals in which this obscure process is going on are called "Hereditary Trotters," because some of these animals, when kept for breeding purposes, transmit the disease during the obscure period; others, on the other hand, do not.

As regards the progress of the disease in a flock, it is always slow and irregular. Once it has got hold of the animals kept for breeding, the cases may at times be very numerous or less frequent, according as external circumstances favour the evil or not. The disease rarely dies out of itself, but it spreads without intermission, so that in the end the fresh stock bred fails to make up for those lost by death. Examples of this have often occurred in the flocks of Silesia.

[1] This classification of the disease into two, according to these two symptoms, should be particularly noted, for in Scotland the same conditions hold. Animals may have the disease and die of it without showing any itching—muscle phenomena alone appearing; and, again, they may die having given evidence only of the itching. See also a similar classification by French authors (*infra*).—[J. P. M'G.]

*Post-mortem results.* — In animals slaughtered immediately after seizure no abnormal changes of any kind are visible in any of the individual organs except when attributable to former states of disease. On the other hand, the carcases of sheep which have succumbed to the disease have shown the following appearances. On the inner surface of the skin, in places where the sheep have rubbed themselves hard, there are effusions of blood or swellings, from a bean to a walnut in size, containing a thick fluid in a dense capsule. In the fluid float corpuscles of the size of hemp seed.

The muscular apparatus is poor in fat, loose, and pale, and any fat that has been present is gelatinously dissolved. In the abdominal cavity the entrails are withered and bloodless, and the blood in the larger vessels is everywhere watery. The large number of intestinal worms to which some animals are subject and which Funke emphasises, as did also, long ago, some French veterinarians, has no connection with the disease itself but is only an accidental occurrence.

The thoracic organs present no striking changes. Seer says that he found red spots like flea-bites extending half a line or more in the vagina and in the neurilemma of the large pelvic nerve trunk. He also states that he found round red gland-like bodies in the mass of fat surrounding the large vascular trunk in the lumbar region. Microscopic examination, however, has shown that these are collections of cells which are present in animals other than those with the "trotting disease."

The opening of the cerebral ventricles and the examination of the spinal cord shows nothing abnormal except a rather increased accumulation of watery fluid, and here and there a softening of the cerebellum. In very many cases, however, the connective and adipose tissues in the central canal of the spinal cord were found filled with serum and appeared like a gelatinous substance. Gerlach, however, asserts that this is nothing but the result of the local fatty atrophy. Almost all studious investigators, from Rudolphi on, have found the membranes covering the spinal cord to abound in blood, and the spinal cord itself (less, however, at the lumbar and terminal parts and cauda equina) to be atrophied, and according to Kuers softened, and on rarer occasions thickened, as Rudolphi and also Störig found. On one occasion Kuers found the cerebellum of a sheep which had been affected with epileptiform "trotting disease" to be so softened that it had almost run out. In individual cases, however, neither in the spinal cord nor in the brain could any diseased phenomena be found. What remained of results corresponded entirely with the condition of cachexia and must be reckoned as such. Funke found the vertebræ more porous and the spinal canal softer than is the case in healthy sheep.

In one sheep affected with the disease in question which had gnawed at its loins, and which was dissected in the Vienna Veterinary Institute, the *dura mater* of the spinal cord was found poor in fat and pallid. The cords of the protruding lumbar nerves were coated with a soft gelatinous reddish exudate which had soaked into the blood-vessels and the delicate fibres of the connective tissue. The spinal cord itself was anæmic, and very moist and soft. The accompanying phenomena

were, intense catarrh of the colon, accumulation of serum in the abdominal cavity, and general anæmia. In a second sheep there was an exudation into the *dura mater* of the spinal cord, and a softening of the spinal cord itself, catarrh of the intestinal mucous membrane, hydræmia, and ascites. Leiserung found practically nothing in three sheep affected with the "trotting disease." A slight atrophy of the spinal cord, together with a somewhat greater solidity of the same, was all he found. Erdt specifies the changes in the spinal cord as, atrophy and softening of the substance of the spinal cord, formation of water in the membranes of the spinal cord along with serous and plastic exudation in the central canal, sometimes a little further forward than, but only in extremely rare cases extending beyond, the lumbar vertebræ. The serous and plastic exudation in the central canal or between the coverings of the spinal cord was the deposited product of an inflammation running a more or less rapid course, and which might even end in apoplectic death should it appear in the anterior parts of the spinal cord. The exudation puts a pressure upon the spinal cord, giving rise to the peculiar phenomena of the "trotting disease."

The statement, made in former times, that in the "trotting disease" vesicles were found in the brain and in the spinal cord is explained by the fact that at that time "sturdy" was often confused with the disease under question, and with the so-called sacral "staggers." In those days one had no adequate knowledge of these different disease conditions. All the same, it is quite possible for a cœnurus vesicle in individual cases to be present in the brain of a "trotter," thus making the "sturdy" a complication. In Silesia, many shepherds believe what Kuers has already told us, that the two diseases act as a supplement, the one to the other. In flocks smitten with the "trotting disease," they are glad when more of the "sturdy" appears, because then they hope that the trotting disease is on the wane.

*Causes.*—As regards predisposition for the disease, we mentioned at some length in starting that the "trotting disease" appears among coarse-wooled sheep, often among the Merino cross-breeds, and most frequently among the Merino sheep. It was reported in the 'Silesian Agricultural News' in 1864 (p. 31) that it also appears among the South Down race, but the fact has not been mentioned by the English writer Youatt. Lepsius bears testimony to the appearance of the "trotting disease" in the cross-breed of the Merino and the Leicester. We can quite understand that many people believed the disease came with the introduction of the Merino sheep. As early as 1759 Leopold described it pretty accurately under the name of "*Traps.*" In 'Contributions to the History of Diseases of Cattle,' &c., from the French of Paulet, published by Rumpet in 1776, we find in Part II., page 221, in the article bearing on the "Staggers," the following: "They rub themselves on the trees and have pruritus in the skin." In other French works the "trotting disease" is erroneously, not to say badly, described as epilepsy and giddiness. Kuers tells us that he even found in one of the Roman agricultural writers a passage referring to the disease in question. Among the Merino sheep it appears more

frequently among the slender, delicately-built animals, those bearing in themselves the fully-developed "Electoral" character, rather than among the large strong animals distinguished for their "Negretti" character. In his article on Negretti sheep, Settegast mentions that the "trotting disease" does not appear among the Negretti sheep. Lastly, the disease appears most frequently among the rams, less frequently among the ewes, and only very seldom among the wethers.

The "trotting disease" is most prevalent in Saxony, Moravia, and Silesia, where the Electoral sheep are most favoured, and where the sale for breeding has grown to great dimensions. Wherever Negretti animals, on the other hand, were reared, and the sale of breeding animals took a secondary place, the disease only appears in individual cases or not at all. To this circumstance is due the assertion that the sheep of the south have less predisposition for the disease than those of more northern countries, which are greatly inclined to the disease from climatic influences.

The disease only attacks animals of one to, at most, four years of age. It is extremely rare for any sheep below or above that age to get the disease. Richter stands alone in recounting cases in a half-year's lamb and in a six-years' old ewe. Lastly, very delicately-built and very fat animals show, in general, a greater predisposition, especially very lively, immoderately lecherous rams which are, moreover, prone to onanism.

Predisposition is inherited by animals begotten by fathers or born of mothers suffering from the "trotting disease." The disease develops whenever the external provocative causes can act upon the animals. *The disease may be even bred in animals though it did not attain development in their parents; and there are not a few cases on record given by Richter and Richthofen where the rams were healthy but their offspring nevertheless were "trotters."* [Italics mine.—J. P. M'G.]

The reasons given up to now for the cause of the disease have been many and various, and, of course, the more incomplete the knowledge of the nature of the disease the less correct they are. And to be quite sincere, up to the present moment the more immediate causes have not been ascertained with absolute certainty. Some, however, may be mentioned which probably do produce the disease; and others, again, which probably have more or less effect upon it.

To the first category belong, prolonged, premature, too continuous breeding of first-rate fine-wooled animals. Especially is this so where rams are used up to their twelfth year, when their procreative power is unnaturally worked up. There is also the disproportionate, excessively strenuous, application of valuable rams for breeding purposes for the sake of a numerous offspring. There is the thrice lambing of ewes in two years, and finally, above all, the too prolonged and continuous pairing of animals already closely related. According to historical information given by Seer in connection with the stock sheep-farms of the Electorate of Saxony, a Merino race had been introduced from Spain in 1777, in which consanguine breeding had been steadily carried on. Twenty-five years later the "trotting disease" was no unusual occurrence. The same thing was experienced at Rambouillet.

All these conditions are bound to exercise an injurious enfeebling influence on the nervous system, and especially on the lumbo-sacral parts of the spinal cord whence come the nerves which branch off into the posterior parts of the body and the genitals. These pernicious conditions are unanimously regarded by the more rational Silesian sheep breeders as first and foremost in engendering the "trotting disease."

In the second category of causes may be placed those influences which hamper and enfeeble the organism to any great extent. Some writers have always laid more or less stress upon these, and to them has even often been attributed the chief cause of the disease. Let us enumerate some of them. Over-nutritious winter food, with the result of fattening the sheep; too rich pasture, in which the normal exciting nutritive ingredients are not found in sufficient quantity; great difference between the summer and winter food—the former too scanty, the latter too abundant; little and bad food, food not sufficient to nourish the body adequately, and which ultimately brings about disturbances in the digestive organs. Seer, in his article on 'Sheep Diseases and Sheep Breeding' (1864), tells how years of famine and the insufficient nourishment of the rams and lambs, on the whole, produced the "trotting disease." He gives many good examples to bear out his assertion. For my own part, I consider the last-named causes as more remote, and those first mentioned as most important in the production of the "trotting disease." If, however, hereditary predisposition exists, it may be produced by the more remote causes, among which even a cold caught at the time of washing may be reckoned. I very seriously discredit what has further been said about heterogeneous cross-breeding, unsatisfied sexual impulse, rich, damp, wet ground, and unwholesome herbage causing the disease. In South Germany, and particularly in Bavaria, Wurtemberg, Baden, and Austria, where, preferably, German sheep, German and Merino cross-breeds, and Negretti sheep, but also the very finest Electoral sheep are bred and kept, these conditions are not less prevalent and active than in North Germany. Nevertheless, to most sheep breeders and keepers there, the disease is not even known by name. Let me in this connection refer to Hering who says in his handbook: "In Wurtemberg, even in the finest flocks, the disease has been extremely seldom met with." In the above-named countries, at an altitude of 1600 feet above the sea, in a fairly rough climate—*e.g.*, the high tableland of Munich—I have had to do with flocks of Electoral sheep for more than two decades. In these flocks, though the causes here denoted as primary are not found, all the others mentioned often act with great severity, and yet there has never been a trace of the "trotting disease."

That there is a predisposition to the transmission of the disease to the nearest offspring cannot be called in question, even in the face of the arguments and counter-evidence brought forward by some writers. It has always been acknowledged by unprejudiced breeders and veterinary surgeons of any penetration. Many unquestionable examples speak for it, some striking cases being given, especially in the volumes on the Möglin Annals. I myself am in a position to

contribute a very unusual case which, as it took place in a country, in a district, and in a flock where the disease was never seen before or after, may be of greater value than one taken from a place where, from the prevalence of the disease in the neighbourhood, its appearance might be attributed to other causes. In the flocks of the Royal Bavarian State Property Administration of Schleissheim, with a stock of Electoral and Negretti races of varied crossings, a flock of over 100 head was brought in from a Silesian Stock farm in 1827. This flock was a victim of the "trotting disease," and from that time forward for a long period the disease raged in Schleissheim, *although the rams descended directly from the diseased flock were, as far as possible, precluded from breeding.* [Italics mine.—J. P. M'G.]

The transmission of the disease to healthy sheep by contagion was taken for granted by many, including Richthofen. He advocates a theory still accepted, that the transmission takes place either by copulation or is effected by means of the nasal mucus secreted towards the close of the disease. This, however, could never be authenticated. Even the experiments specially made by Thaer, Kanert, Ernst, Störig, Spinola, Funke, with a view of effecting contagion, as also the vaccinations undertaken for the same purpose, had always a negative result. *There can therefore be no question about the contagiousness of the disease. The District Veterinary Surgeon in Polish Wurtemberg says it is impossible to accept the theory of the contagion of the "trotting disease," because then no first-class sheep could exist in that district at all, seeing the disease was much more widespread than people acknowledged.* [Italics mine.—J. P. M'G.]

*Prophylaxis.*—Having enumerated above the primary and more remote causes of the "trotting disease," the means of guarding against it may be summed up in the following points. Do not rear sheep with too fine wool, which have exceedingly delicate bodies and too weak constitutions; give preference rather to strongly-built robust animals, feed them from youth on with appropriate regularity and natural food, and neither pamper nor spoil them. Avoid premature and too prolonged application for breeding purposes of the males and also of the females; do not give too many ewes to the rams, and do not breed too long among closest relations. When causal conditions well known in the locality begin to show, try if possible to neutralise and avoid them; and, as far as you can, try to prevent them from getting hold of the flock. Should this fail, the acquisition of a more robust race, or the relinquishment of sheep-rearing altogether, remains the only method of getting rid of the disease.

*In buying rams and ewes be careful not to get them from flocks infested by the "trotting disease." The most careful investigation is here necessary, for in such flocks an attempt is always made to conceal the fact as well as possible. If the disease breaks out in a flock, under no circumstances employ the suspected animals for breeding; on the contrary, kill at once and spare not, especially at the outbreak of the disease, every animal in which the evil has been confirmed, and give unceasing and most careful attention to their offspring, so that any suspected animals may, without delay, be prevented from breeding.* [Italics mine.—J. P. M'G.]

The next reference of importance to the disease in Germany is in a paper by Cassirer (3) in 1898. He made a careful clinical examination of five Traberkrankheit sheep, and the following are some of his observations:—

In accordance with what is already known, the chief symptom I have been able to determine in the animals is a paresis, which generally begins at the hind-quarters, increases in intensity here during the course of a few weeks, and also spreads over to include the fore-quarters. At first this consists of an awkwardness and incertitude of movement, so that one could well speak of it as a kind of ataxia, if the jerking in carrying out of the movement was not also present. Later on the loss of the power of moving increases so much that the animal can only stand and walk with difficulty, and finally it is unable any longer to get up from the lying position. It must, however, *be carefully noted that a complete paralysis of the muscles of the extremities affected has never been observed*, and that the undoubted weakness of the muscles must be attributed in whole or in greater part to the general condition. [Italics mine.—J. P. M'G.]

The patellar reflex, which we examined regularly, as comparison with that of numerous healthy sheep showed, was normal. The Achilles tendon reflex was elicited in some cases, in others not, but this corresponded with the condition in normal animals. In case I. the electrical reactions were normal in the affected sciatic region, and we have every reason to believe that in the other cases above the same holds good. We could not find any local muscle atrophy in the region of definite nerves.

Dealing with other symptoms, there are difficulties in estimating the state of sensation in such an animal, and it is not necessary to go into it any further. We could only once find signs of a blunting of sensibility, and that in the last days of life of sheep V. Here the blunting of sensibility to needle-pricks can be explained best by the general severe condition which then already has brought about a very definite damage to the constitution as a whole. As regards the symptoms of gnawing and rubbing, which one has to look at as an expression of paræsthesia, in some cases these were present, in others not. The function of the bladder and of the rectal centres and nerves seemed always to be intact.

As regards other symptoms, it was several times noticed that, either spontaneously or by delicate stimuli, one could easily excite a chewing movement.

For some time we believed that we had discovered that the reflexes of the skin muscles, especially in the posterior part of the body of the "trotting sheep," were increased; further observations, however, showed that this symptom is not constant and is modified by various other circumstances—thickness of skin and wool.

As an important symptom other observers have mentioned the great excitability and fear in "trotting" animals. It is quite to be understood that we were not always able to verify clearly this sign of increased psychic irritability in our animals, as we were observing

the animals under quite abnormal conditions. However, on several occasions it seemed that the shyness and fear of the animals was actually increased as compared to normal control animals.

The death of the animal usually takes place, without complicating diseases, as a result of marked lowering of the nutrition. In one case there was a pneumonia as a cause of death; in the four other cases the *sectio* gave us no clue to the cause of death. *If we try to get a picture of the nature and seat of the disease from the clinical examination only, we hardly get any further than that we can exclude certain parts of the nervous system (to an affection of this system without doubt most of the symptoms point). The nature of the disturbance of movement points to the motor protoneuron not being the seat of the disease. Against such a site everything speaks. Local muscular atrophy is absent, qualitative changes in the electrical reactions are absent, and the tendon phenomena are all retained. Also for an affection of the peripheral sensory nerves there is no indication; therefore only the central nervous system remains, as also a primary muscular affection cannot be considered. A closer localisation in this region from a clinical standpoint seems to be futile.* [Italics mine.—J. P. M'G.] Only one more point may be brought forward. The assumption that one has to deal with a disease which is similar to *Locomotor ataxia* of man has no clinical support; for although the disturbance of movement suggests a disturbance of co-ordination, yet the retention of the tendon phenomena speaks quite definitely against *Locomotor ataxia.*

As regards finding the key to the disease from an anatomical examination of the nervous system, we have not obtained it even by a very exhaustive exact microscopic examination of the whole nervous system. For the result was, as could be concluded from the very beginning, for all practical purposes negative.

The following further extract from Cassirer's article, page 99, has an important bearing on the subject. It is as follows:—

Fig. 4 shows a piece of the gluteal muscle from "trotting" sheep I. The cross section of the muscle has a normal appearance, and on longitudinal section one sees very well the cross striation. Between the muscle bundles one sees lying in the figure given very numerous (eight in one field) round figures (in other sections these are less numerous) which, stained deep yellow, consist of refractile coccidia like balls, which, as the longitudinal section also shows, are lying in such a way in the muscle fibre that they sometimes bulge out this slightly, but yet leave the substance wholly intact. *There can be no doubt that we have to do in these bodies with psorosperm corpuscles which have been called Rainey or Miescher's corpuscles,*[1] *and which largely present in different animals are considered as moderately harmless inclusions which we in no way can bring into relation with the*

[1] Sarcosporidial cysts.—[J. P. M'G.]

*symptom complex observed during the life of the animal.* [Italics mine. —J. P. M'G.]

It is to be noted in passing that this is the only positive pathological condition found by Cassirer, in his five diseased sheep, which *a priori* one would think would have any bearing on the disease. How much importance he attached to this fact can be seen from the above extract, and also from the concluding sentence of his paper, where he says:—

> Concerning the nature of the disease we may save ourselves the trouble of forming further hypotheses. Since anatomically and bacteriologically no positive result has been got—we would only be dealing with unprovable hypotheses by doing so.

Some reference is made to the disease in Friedberger and Fröhner's 'Veterinary Pathology' (4), and in Hutyra and Marek's 'Special Pathology and Therapeutics of the Diseases of Domestic Animals' (5). These accounts are very brief, and bear no comparison with the excellent one given above by May. Some further points which they have brought forward will, however, be mentioned here. Friedberger and Fröhner (p. 693) state that the males sicken most readily, especially young rams from two to three years; females and wethers less frequently. As a prophylactic, they mention amongst other things that rams should not be used till after their second year. Hutyra and Marek (p. 757) state that the disease was practically unknown previous to the end of the eighteenth century, but that it has occurred with great frequency since that time. According to them this coincides with the introduction of the Merino breed, and with the plan of improving the breeds of sheep to an excessive degree with the object of improving the wool. They note, however, that the disease had been previously observed, for it was mentioned by Leopold in 1750, when great losses were experienced in Spanish sheep, the breeding of which was then greatly increasing, and among which inbreeding was resorted to with the object of improving the breed.

As regards the causation, they make the following statements:—

> The actual cause of the disease is unknown. The disease has been described as exceedingly contagious, not only by breeders but also

by veterinarians. There is much evidence indicating that the disease is not hereditary. The principal point is that the disease occurs among sheep that are not pure bred, such as English and German sheep bred for mutton. It is alleged that goats are also attacked. The disease also occurs among pure-bred sheep derived from perfectly healthy parents. Furstenberg records an outbreak that was so severe that almost every animal in a herd of 500 became ill and one-third of them died.[1] Cases of this sort absolutely exclude the possibility of heredity having anything to do with the transmission of the disease. Evidence pointing in the same direction is that the progeny of certain rams become ill in one district and not in another, and, further, the complete disappearance of the disease from herds that are severely affected when the herds are transferred to other districts. Even this factor was not considered completely satisfactory by the supporters of the theory, other causes being also blamed, such as an excessive use of young rams, feeding with rich food, or, on the other hand, with poor food, and sudden changes of food. These factors have not been shown by more recent investigations to play any part in the production of the disease.

The fact that the disease occurs in certain districts, in some cases in particular parts of these districts and especially in damp marshy places, suggests that it is due to an infection of some sort. The infection theory put forward by Richthofen has more recently found supporters in Besnoit and Morel, although these admit the possibility that it may be due to an intoxication set up by some food-stuff. Cassirer has been unable to transmit the disease to sound animals by the transfusion of blood, but in the blood and cerebro-spinal fluid he found large cocci, which after intravenous inoculation persisted in the blood of healthy sheep for long periods and then disappeared. One experimental sheep died after a year from exhaustion without having shown any symptoms of the disease.

A special predisposition on the part of certain breeds of sheep accords well with the theory of infection. The special susceptibility of the Electoral sheep may be due to the excessive improvement of the breed, to inbreeding, and to pampering. Susceptibility to other contagious diseases is seen under similar circumstances. The occurrence of the disease after the introduction of fresh stud animals and the subsequent spread, are consonant with this theory. On the other hand, a spontaneous occurrence of the disease does not completely militate against the possibility that the disease is of an infectious nature, in that it is not always easy to prove that an infective material has not been introduced.

Describing the symptoms, they say (p. 759):—

The most striking symptoms in the early stages are, as a rule, excitability and fright. The animals have a scared look, and the approach of a person or animal is sufficient to so frighten them that

[1] These would appear not to be cases of the disease under consideration. —[J. P. M'G.]

they stand and tremble. The appearance of a dog may cause collapse and epileptiform seizures.

In the early stages the animals gnaw at the root of the tail, the gluteal region and loin, and later the hind and fore legs, or they rub these parts of the body against the wall. In some cases they sit like dogs so as to be able to reach the irritating parts better with their teeth.

In spite of the fact that the appetite remains good up to the end, emaciation, anæmia, and hydræmia become more and more pronounced. Recovery is very exceptional, and when it occurs it is in the early stages of the disease.

The course of the disease tends to be more rapid in summer than in winter, and in young animals than in adults. There may be apparent improvements from time to time, but the disease terminates fatally in two to four months.

These extracts are quoted here to complete the picture of the disease as it exists in Germany. They will be the subject of comment later. Meantime, however, the consideration of the disease as it occurs in France will be proceeded with.

Unfortunately, comparatively speaking, very little information has been obtained about the disease as it exists in France. This may be due to the fact that it has not been studied much there, or—what may be more likely—to the fact that the reports and descriptions of the disease occur in local and provincial papers which, not having a wide circulation, are not easily obtained. Besnoit and Morel (6), while speaking as follows, "In spite of its frequency, in spite of its ravages, often considerable in the district where it is endemic, the disease 'Trembling' has, up to the present time, only been the subject of a very small number of pathologico-anatomical researches," do not mention any of the symptoms of the disease. Bigoteau and Bissauge, the authors of the latest book in French on the diseases of the sheep, mention what appears to be the disease on page 209, under the name *Méningite cérebrospinale des adultes.* Unfortunately, not only has a new name been given to the disease, but the whole subject has been confused by the obvious desire of the authors to make the Preisz-Nocard bacillus and its toxin responsible for the majority of diseases in sheep. This disease is thus, according to them, due to the "Toxin of the Preisz-Nocard organism" (p. 209). No proof whatever is offered for this bald statement.

Tessier is said by them to have mentioned it, under the name of "Maladie convulsive," or "Maladie folle." Thaier, about 1819, gave it the name of "Vertigo." Further, they state that Girard, Director of Alfort, studied the disease in 1821 under the name of "La tremblante." Roche Lubin, in 1847, addressed a Memoire to the Society Centrale on the same affection, which he had studied in the Larzac. Cauvet has seen it in a flock of wether lambs of eight months. Trasbot, several years later, saw it in a flock in a number of ewe lambs, from ten months to a year old. Rieussec, Besnoit and Morel, Roll, Weber, Roloff, and Berger, according to them, have likewise studied it. Unfortunately, no reference is given to the publications where the work of the authors mentioned appeared, so that, with the exception of that of Besnoit and Morel, one is unable to consult the original articles. This would have been desirable, for statements such as, that the disease appeared in lambs of eight months to a year, raise suspicions as to whether the authors are not really dealing here with two diseases. While admitting that the disease occurs at this age and younger (see May, *supra*), it cannot be said that it is at all common. From these references such cases would, however, appear to have been very common even in one flock. On page 210 is given a brief description of the disease, and the only points of importance appear to be the following. The authors state that

> the animal bleats with a peculiar timbre, which indicates a lesion of the brain. . . .
>
> Later, in certain of the diseased animals pruritus appears: the patient rubs the back, bites the tail and legs: the pruritus reaches the loins, the sheep lies down to bite itself without ceasing. It is then that the skin is covered with crusts and exudate which makes one believe that the disease is scab. It is this pruritus which has given the name of "lumbar prurigo" to the disease. This name should not be preserved, for the symptom is far from being constant. Paralysis and death come on often without its appearance. . . .
>
> The old shepherds, the *hippiâtres*, and the veterinary surgeons of early days attributed the appearance of the disease in France to the introduction of Merinos from Spain, and all the observers saw the disease more often in choice and improved flocks and among the milk sheep of Larzac than in other flocks (p. 212).

Evidently the disease is not considered contagious by the authors, because in the preventive treatment no mention is made of measures to combat such a mode of spread.

It is a curious but very noticeable fact that in England, Germany, and France, the most accurate descriptions of the clinical symptoms, &c., of the disease are not by the modern but by the older writers. This has been shown for England and Germany by the extracts given above. Bénion's (8) (1874) description of the disease as it occurred in France is now given :—

*La tremblante*, further named in France the "trembling" disease (*maladie tremblotante*), the "convulsive" disease (*maladie convulsive*), the "mad" disease (*maladie folle*), the "staggering" disease (*maladie chancelante*), disease of nerves (*mal de nerfs*), vertigo (*brandillon*), "shakings," "lumbar prurigo"; in Germany the "gnawing," the "whetting" or "shrugging" disease is a non-febrile disease of long duration which exists among sheep, more rarely among goats. The affected animals are timid and easily frightened; the sensitiveness of the spinal nerves is considerably augmented; there gradually appears a certain weakness of the hind-quarters, with paralysis finally, and the fatal termination supervenes with considerable emaciation.

Gerard [senior], Röll, Roloff, Wehenkel, and Lafosse are the authors who have best discussed the disease. . . .

*Etiology.*—This disease attracted attention only when the rearing of high-bred sheep was undertaken on a large scale and had spread widely. It had been observed only in isolated cases before the introduction of foreign breeds; its spread was intimately associated with the refinement and softening of these animals. One meets a special predisposition to the development of the disease amongst animals descended from parents affected with the disease, as well as from those which have been admitted too soon or too late to breeding. It shows itself then in this case as a hereditary affection. The same predisposition exists also among high-bred animals which are very susceptible to unfavourable external conditions, especially if one has brought about this quality by feeding on very nutritive plants and by luxuriant vegetation. The disease appears most frequently at the age of two to three years, and attacks by preference the males, more especially, some say, if they are used too frequently for breeding; as occasional causes one thinks of such things as too rich feed, &c. . . . *The view formerly held of the existence of a contagion as the cause of this affection has not been confirmed by the latest observations.* Locality has a certain influence on the appearance of the disease. According to Roloff, this disease is not the necessary consequence of the grading up of sheep: *the disease is not of a contagious nature: the predisposition to this disease can be transmitted hereditarily, but this transmission is not constant.* Among individuals predisposed, the disease is provoked by the action of some chance cause which need not be, however, in all cases a condition absolutely harmful. . . . [Italics mine.—J. P. M'G.]

*Symptoms.*—One usually recognises two varieties of this disease. In one the convulsive phenomena predominate; in the other lumbar

prurigo is the principal characteristic. (1) *Convulsive variety:* at the beginning the ears are lowered and the conjunctiva injected, the appetite is preserved; but usually there is some stiffness of the lumbar region which is arched up; further, one soon observes restriction of movement; the hind-quarters stagger and at intervals there appears trembling all over of short duration, after which calm is again restored; later convulsions take the place of the tremblings; the whole body stiffens or the stiffness is concentrated especially in some region, notably in the neck or the lips. There is also during the convulsive seizure dilatation of the pupils, rolling of the eye, and the appearance of the nictitating membrane on its surface. Cauvet has noted that the beasts hold the head high and the tail raised at its base, and that if one approaches them, they try to get away, shake on their legs, tumble, are agitated with convulsive shakings, but are not long in getting up if one leaves them quiet. Thus developed, the disease lasts quite a time. Some animals resist several months; others for two to three or four weeks only. Towards the end the attacks become more frequent; when they cease they leave the animal dizzy and prostrated for a longer and longer period; at last they become so feeble that they can no longer stand on their legs; then, although the appetite is preserved digestion is not good, flatulence becomes pronounced, and death supervenes.

(2) *Pruriginous variety.*—It shows itself by intermittent bitings, at first limited to the tail. The animal rubs itself also against resistant bodies; the pruritus becomes more active and spreads to the rump and the lumbar region; the tail is violently shaken during an attack. The animal scratches or bites itself so much that it pulls off its wool and bares itself. Most of the animals bite their limbs and tail so much that not only do they denude themselves, but they also produce excoriations; they lie down in order that they may better bite themselves. When the disease gets to this stage the beasts have a restless wandering look; they are easily frightened; they hold the head high and the ears low; their gait is formal; later, they become shaky behind or before, and stumbling takes place; at last they remain lying for longer periods, and a time arrives when standing is no longer possible for them; the little power the animal has it uses up in biting itself; the eye becomes rolling and haggard; the pupil remains dilated; the conjunctiva becomes a livid red; but the appetite and thirst are preserved up to the end. It is remarkable that the bitings which characterise the disease during its whole course are not accompanied by any skin eruption.

In this last form the disease is usually a little more prolonged than in the first variety.

*Post-mortem appearances.*—The only *post-mortem* appearance worth recording here is the following:—

At the places where the animal has rubbed itself most vigorously one sees very often tumours of a size varying from that of a haricot

bean to that of a nut, or even to that of a hen's egg, situated in the subcutaneous cellular tissue.

Whilst as regards prognosis and treatment, the following statements are made:—

Prognosis is absolutely unfavourable, and any treatment is useless: prompt slaughter of the sick animals is best. As regards prophylactic measures, one must take care *to exclude rigorously* from breeding every sick ram or ewe, every animal which has not passed his second year as well as the old and done tups. . . . Avoid buying breeding animals from flocks where this disease exists.

In this chapter the descriptions of a morbid clinical entity in the sheep in Germany and France by various German and French authors have been brought together. After due consideration and comparison there would appear to be no doubt that the disease scrapie of Britain is identical with this condition. Cassirer's findings (*vide supra*) in connection with the pathology of cases of the disease should be noted; and it should be specially observed that the preponderant view both in Germany and France is that the disease is not contagious, but transmitted from parent to offspring. In passing, it may be pointed out that the disease has been noted in goats by German and French observers (*vide* Hutyra and Marek, and Bénion, *supra*). Other points brought out in this chapter could be emphasised, but these will suffice for the present.

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(3) Cassirer. Ueber die Traberkrankheit des Schafes; Virchow's Archiv. 1898. Bd. CLIII. p. 89.
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(6) Besnoit and Morel. C. R. Soc. Biol. t. V. 1898. p. 536.
(7) Bigoteau et Bissauge, Hygiène et Maladies du Mouton. Paris, 1912. p. 209.
(8) Bénion, Traité complet de l'Élevage et des Maladies du Mouton. Paris, 1874. p. 444.

# CHAPTER III.

## SYMPTOMS AND PATHOLOGY OF THE DISEASE.

In this chapter it is proposed to set down various clinical facts, which I have observed by keeping scrapie sheep under more or less close observation in the laboratory, and also to give in some detail the post-mortem findings in such cases. The method of the clinical observation will be seen from the description of the separate cases; but to avoid repetition it would be well to state at once, in detail, the method employed in nearly all the cases for the post-mortem examination.

Before opening into the sheep the external surface of the body was carefully examined, for swellings, abrasions, loss of wool, ectoparasites, emaciation, discharge from orifices, &c. The sheep was then skinned, and the condition of the subcutaneous tissues observed, attention being specially directed towards the presence or absence of fat, formation of abscesses, and of pockets containing loose fatty bodies. The thorax was then opened into by cutting through the ribs on both sides of the sternum, and removing the sternum *en bloc*. A culture was then made from the heart blood by piercing the heart wall with a sterile pipette, sucking up the blood and inoculating agar and broth tubes. The condition of the heart muscle was then observed, especially with regard to presence or absence of fat and gelatinous œdema; the pericardial sac was also examined for presence of fluid. The lungs and pleural sacs were next examined, as also the trachea, cultures being made from the last. The œsophagus was then examined for the presence or absence of the large cysts of the sarcosporidium Balbiana gigantea.[1] The thyroid, larynx, pharynx, tongue, salivary glands, were also examined. The abdomen was next inspected, and the organs, such as the liver, spleen, kidneys, pancreas, &c., gone over

[1] This term is now practically given up, but its use is continued here as a convenient method of indicating this condition.

*seriatim*. The suprarenals were examined for chromaffin substance. The genito-urinary apparatus and the mammary gland were examined carefully, especially for the presence of sarcosporidial infection. The alimentary tract, in its whole length, was subjected to very careful scrutiny, especially for anything of the nature of a sarcosporidial infection, for the presence of acid-fast bacilli and of entoparasites.

Cultures were made from the cerebrospinal fluid, by drawing off the fluid with a sterile pipette through the atlanto-axial ligament. Smears were examined from the blood, bone-marrow, spleen, liver, kidney, and lungs.

The following organs and tissues were examined microscopically in sections: heart, lung, œsophagus, thyroid, tongue, salivary glands, liver, spleen, kidney, pancreas, udder, testicle; the various regions of the male and female genitals; the urinary tract, in male and female; the separate regions of the alimentary canal; the different regions of the spinal cord; the posterior root ganglia; the sciatic, and some cords of the brachial plexus.

The muscles from various parts were examined microscopically in teased preparations and in sections.

### Case 1. (June 19, 1912).

Half-bred gimmer[1] from Northumberland; one of a lot from which a large number had died during the preceding winter from "scrapie." It had a lamb in March, but the lamb died. It has been getting progressively thinner for some time. Wool not rubbed off; when scratched on flanks, shows evidence of itchiness; no diarrhœa at any time; great thirst; takes a large amount of food; can be handled quite freely—no evidence of shyness.

The blood was examined and the temperature in the rectum taken on June 19, with the result in Table I.

TABLE I.

| Red Blood Corpuscles. | White Blood Corpuscles. | Hæmoglobin. | Microscopic Examination. |
|---|---|---|---|
| 9-10,000,000 | 12,000 | 65% | Some variation in the size of R.B.C. No abnormal W.B.C. |

Temperature=40·5° C.

[1] Female sheep from the age of 12 to 24 months.

The animal was then killed with $CHCl_3$, and the routine post-mortem performed. The following points of interest were found at the *sectio* :—

No Balbiana in the œsophagus.
A few filaria and Strongylus rufescens in the lung.
A few strongyles in the fourth stomach.
No acid-fast bacilli in intestine.
No growth from heart blood or cerebrospinal fluid.
No growth from trachea.
A few sclerostomes in small intestine, and trichocephalus in colon.

No other pathological condition was observed in the animal except that there were from 5 to 10 sarcocysts per 15 milligrammes of the muscle.

### Case 2. (July 1, 1912).

Half-bred ewe from Roxburghshire, between two and three years old; received July 1, 1912. Wool not rubbed off; no diarrhœa; is itchy, and has some scabs on nose; getting very thin; had two lambs in March; eating its food well.

### TABLE II.

*Blood.*

| | R.B.C. | W.B.C. | Hb. | Microscopic Examination. |
|---|---|---|---|---|
| July 1 | 8-9,000,000 | 30,000 | 55% | Red blood corpuscles uniform in size. Polymorphs 72%, Mononuclears 27%, Eosinophils 0·75%, Masts 0·25%. |
| 2 | 8-8,500,000 | 22,400 | 60% | |

It was killed with $CHCl_3$ on July 4, and the following are the points in the post-mortem :—

Very little body fat, and animal emaciated.
No Balbiana in the œsophagus.
A few Strongylus rufescens in lungs.
A few strongyles in the fourth stomach; no other intestinal parasite found.
No growth obtained from the heart blood, trachea, or cerebrospinal fluid; no cells in centrifuged cerebrospinal fluid.
Fat in skeletal muscles and in auriculo-ventricular groove very gelatinous.
No acid-fast bacilli found in intestine.

The only pathological change of importance was the large number of sarcocysts in the muscle—10 to 15 per 15 milligrammes of muscle.

FIG. 3.—Case 4. Half-bred Ewe with Scrapie. Note the emaciation, the abrasions on the legs, and the swelling on the nose. There is no falling off of the wool on the flanks.

FIG. 4.—Head of Case 4. Showing the swelling on the nose, the abrasions, and the wool rubbed off.

CASE 3. (Aug. 2, 1912.)

Half-bred gimmer received August 2, 1912. Very thin; keeps rubbing rump and top of head; wool not falling off; no diarrhœa; been eating its food well; drinks a great deal of water; it can hardly stand; when it does so its legs tremble beneath it. Temperature has been ranging for some time between 39° C. and 39·5° C. The blood was examined on August 2, with the result in Table III.

TABLE III.

| R.B.C. | W.B.C. | Hb. | Microscopic Examination. |
|---|---|---|---|
| 10,200,000 | 10,000 | 95% | Polymorphs 35%, Mononuclears 64%, Eosinophils 1%. |

While the blood was being taken the animal died quite suddenly.

Post-mortem, there was a large quantity of fluid in the pericardial sac.

Some strongyles in the stomach.

No worm patches in lungs.

No Balbiana in œsophagus.

No growth in cultures from heart blood or cerebrospinal fluid.

No acid-fast bacilli in intestine.

Again the only pathological change of importance was the large number of sarcocysts in the muscle—5 to 10 per 15 milligrammes of the muscle.

CASE 4. (Nov. 4, 1912.)

Half-bred ewe, between two and three years old. The wool and hair were rubbed off the top of the head, eyebrows and front and side of nose, root of tail, and the legs (see figs. 3, 4, and 5); there was very frequent micturition, especially when the animal was touched. When the animal was held fast it began to groan, defæcating and urinating the while. There was no diarrhœa; its appetite was very good. In spite of this it became progressively more emaciated; there were swellings on the outside of right hind leg and on nose; great thirst was present. The animal was received on November 4, 1912, and kept under observation till November 28. Observations as follows were made on the temperature, the blood, and the urine:—

*Temperature.*

The temperature was taken every other day for a period lasting about a month, and during this time it remained between 39·5° C. and 40° C.

## TABLE IV.

*Blood.*

| | R.B.C. | W.B.C. | Hb. | Microscopic Examination. | | |
|---|---|---|---|---|---|---|
| Nov. | | | | | | |
| 6 | 7,000,000 | 12,000 | 60% | — | | |
| 11 | 5,300,000 | 5,600 | 50% | Nothing abnormal in blood films. | | |
| 12 | 5,000,000 | 7,400 | 56% | — | | |
| 13 | 5,910,000 | 11,400 | 58% | Nothing abnormal in blood films. | | |
| 14 | 6,210,000 | 9,600 | 58% | ,, | ,, | |
| 15 | 6,350,000 | 9,000 | 56% | — | | |
| 16 | 6,150,000 | 8,400 | 58% | — | | |
| 19 | [1 P.M.] 5,960,000 | 8,600 | 54% | Nothing abnormal in blood films. | | |
| | Animal laid among ice and water to test effect of this treatment on the blood. | | | | | |
| 19 | [2.30] 5,850,000 | 7,000 | 52% | Nothing abnormal in blood films. | | |
| 20 | 5,930,000 | 8,600 | 56% | ,, | | ,, |
| | | | | Polymorphs. | Monos. | Eosin. |
| 21 | — | — | — | 58% | 42% | None |
| 22 | [4.30] — | — | — | 38·5% | 61% | 0·5% |
| | [10.30] — | — | — | 68% | 32% | 0% |
| 23 | — | — | — | 35·2% | 64% | 0·8% |
| 24 | [11.30] — | — | — | 53% | 47% | 0% |
| | [5.30] — | — | — | 56·5% | 43% | 0·5% |
| 25 | 5,280,000 | 6,000 | 58% | 59% | 41% | — |
| 26 | — | — | — | 58% | 42% | — |
| 27 | — | — | — | 40% | 60% | — |
| 28 | 5,350,000 | 6,600 | — | 57% | 42·5% | 0·5% |

Fresh films examined every day. No trypanosome seen at any time, or any other blood parasite.

## TABLE V.

*Urine* (which was uniformly clear).

| | Nov. 12. | Nov. 18. | Nov. 24. | Nov. 25. | Nov. 26. | Nov. 27. |
|---|---|---|---|---|---|---|
| S.G. | 1004 | 1004 | — | 1010 | — | — |
| Urea | — | 0·2% | — | — | — | — |
| Albumen | 0 | ? | — | ? | — | — |
| Total Nitrogen | — | 0·125% | — | — | — | — |
| Sugar | 0 | 0 | — | 0 | — | — |
| Bile | 0 | 0 | — | 0 | — | — |
| Blood | 0 | 0 | — | 0 | — | — |
| Chlorides | Trace | 0·07% | — | — | — | — |
| Carbonates | Trace | Trace | — | — | — | — |
| Deposit | None | None | — | None | None | None |
| Reaction | Alkaline | Alkaline | — | Alkaline | Alkaline | Alkaline |
| Colour | Yellow | Yellow | Yellow | Yellow* | Yellow | Yellow |

Nov. 26.—Urine centrifuged and a few large epithelial squames found.

* Pigments are urochrome and urorosein.

On November 20, 10 c.c. blood was drawn from the external jugular and inoculated into broth and agar tubes, which were incubated at room I.°, 30° C., and 37° C. No growth was obtained in any of the

FIG. 5.—Hindquarters of Case 4. Showing the ischial tuberosities bared of wool by rubbing.

FIG. 6.—Case 6. Half-bred Ewe with Scrapie. There is nothing in the demeanour of the animal at the time of the photograph to indicate that it is ill.

tubes. The fæces and rectal mucus were examined several times for acid-fast bacilli, and none found.

The animal was killed with prussic acid on November 29, and the following are the important points in the post-mortem :—

No acari found on skin.
Several subcutaneous abscesses where skin rubbed.
Old standing pleurisy.
Some worm patches in lungs with Strongylus capillaris and rufescens.
Muscles very gelatinous looking.
No Balbiana in œsophagus.
Excess of fluid in pericardium.
Fat on surface of heart has undergone gelatinous degeneration.
No omental or kidney fat.
No loss of chromaffin substance in suprarenals.
Slight ascites present.
No acid-fast bacilli found in any part of the intestine or in the mesenteric glands.
Strongylus contortus present in small numbers in the fourth stomach and a few Sclerostomum hypostomum in the duodenum.
No growth obtained in cultures from lungs, trachea, heart-blood, cerebrospinal fluid, or peritoneum.
The fat surrounding the cord in the vertebral groove had undergone gelatinous degeneration
Cord, nerves, and posterior root ganglia examined, and nothing abnormal found except some possible slight changes in the posterior root ganglia.

Examination therefore, naked eye at first, and subsequently microscopically, showed nothing of importance in this case except the presence of sarcosporidia in numbers varying from 10 to 20 per 15 milligrammes of heart and skeletal muscle.

### Case 5. (Nov. 28, 1912.)

Cheviot ewe, three to four years, received November 28, 1912. While appetite preserved, it becomes gradually more and more emaciated. Bleaching of the wool over the loins at first (later the wool fell out, leaving a bare moist patch behind). The animal is constantly rubbing its sides, forehead, &c., on fences and walls. When its sides are pinched, it bites furiously, works its nostrils, bends its back, and rubs against the wall. The animal was constipated until a few days before its death, when it began to eat less, had diarrhœa, and became so weak that it could not stand. Its weight varied from 90 lb. on December 9 to 82 lb. on December 16 and 23; to 70 lb. on December 31; to 75 and 72 lb. on January 6 and 9 respectively; to 65 lb. on January 17.

#### *Temperature.*

The temperature in this case was taken every second day for a month and a half, and with the exception of a single rise to 41° C. befor death, remained between 39·5° C. and 40° C. all the time.

The blood was also examined frequently during the same period with the results in Table VI.

TABLE VI.

| | R.C.B. | W.B.C. | Hb. | Microscopic Examination of Fresh Films. | Microscopic Examination. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Polymorphs. | Monos. | Monos. (with inclusions).* | Eosin. |
| Dec. | | | | | | | | |
| 2 | 10,600,000 | 5000 | 90% | Nothing abnormal | 22% | 69% | 5% | 4% |
| 4 | 10,750,000 | 5300 | 78% | ,, | 25% | 70% | 3% | 2% |
| 7 | 9,850,000 | 4400 | 70% | ,, | 21% | 74% | 2·6% | 2·4% |
| 9 | 9,565,000 | 4900 | 82% | ,, | 26% | 68% | 2·3% | 3·7% |
| 11 | 9,750,000 | 5600 | 80% | ,, | 29% | 67% | 0·7% | 3·3% |
| 13 | 9,900,000 | 6200 | 78% | ,, | 29% | 67% | 3·5% | 0·5% |
| 16 | 9,600,000 | 5000 | 82% | ,, | 38·5% | 57·5% | 0·25% | 3·75% |
| 23 | 8,650,000 | 5800 | 75% | ,, | 62·5% | 35·5% | 1·5% | 0·5% |
| 27 | 9,300,000 | 6200 | 78% | ,, | 58·3% | 40% | 1·4% | 0·3% |
| 31 | 9,150,000 | 5600 | 75% | ,, | 49·5% | 48% | 2·5% | — |
| Jan. | | | | | | | | |
| 6 | 8,720,000 | 6800 | 76% | ,, | 56·2% | 41·6% | 2·2% | — |
| 9 | 9,200,000 | 5800 | 76% | ,, | 48·5% | 48·5% | 3% | — |
| 17 | 10,700,000 | 8000 | 100% | ,, | 87% | 12·5% | 0·5% | — |
| 18 | 12,340,000 | 8800 | 98% | ,, | 91·2% | 8·5% | 0·3% | — |

* Many of the mononuclear cells of the sheep contain inclusions in their protoplasm which take on a basic dye. It was thought for a time that these might have some bearing on the disease, and in some of the cases they were counted differentially.

The animal having for several days been off its feed,—fevered,—affected with diarrhœa,—and becoming gradually weaker, died during the night of January 20. The points noted post-mortem were as follows :—

Presence of diarrhœa.

Subcutaneous pockets containing fat-like bodies free in the cavities; these pockets were present at places where the animal had been rubbing.

Bronchitis and œdema of lower lobe of right lung.

Infarction and œdema of middle lobe of right lung.

Worm nodules and bronchitis of upper lobe of right lung.

Left lung, normal except for a few worm patches.

Body fat—fair amount, not œdematous or gelatinous.

No Balbiana in œsophagus.

Liver and kidneys fatty.

Pregnant with twin lambs.

Catarrh and congestion all down alimentary canal.

No acid-fast organisms found.

Striped muscle from all parts of the body examined for sarcosporidia, and their presence determined in large quantities (20-30 per 15 milligrammes). No sarcosporidia found anywhere in non-striped muscle, or in udder, teats, or genito-urinary tract.

No acari on skin; few Strongylus contortus found in fourth stomach.

Heart-blood and cerebrospinal fluid cultures sterile.

Brain, cord, posterior root ganglia, and sciatic nerves examined microscopically and no pathological change found.

Evidently this animal had died from some acute infection superimposed on the chronic condition, and, again, here the only pathological change of note of a chronic nature was the abundant sarcosporidial infection.

### Case 6. (March 12, 1913.)

Half-bred ewe; 4 crop. Had a lamb on March 19. Received at the laboratory on March 27. At this time the animal was fat, healthy, and without any sign of the disease (see fig. 6) except a slight infrequent irritable twitching of the tail. Rubbing and itchiness at first were not marked, but gradually became more noticeable, until on April 8 it began to bite savagely whenever its head was rubbed or its back scratched. By May 12 it was often observed to be sitting on the ground like a dog and rubbing its hindquarters on the ground. By the middle of April the wool on the back was bleached and hanging down in long tags. It became progressively thinner, while taking its food well to the end. There was no diarrhœa at any time. The milk was examined for possible stages of the parasite, but none were found.

The weight, which was 125 lb. on April 14, became 121 on April 23; 118 on April 30; and 110 on May 9.

#### *Temperature.*

Temperature, taken every other day for a month and a half, remained between 39·5° C. and 40° C.

Subjoined is a table of the results of the blood examination (Table VII).

TABLE VII.

| | R.B.C. | W.B.C. | Hb. | Polymorphs. | Monos. | Monos. (with Inclusions). | Eosin. |
|---|---|---|---|---|---|---|---|
| Mar. 27 | 9,900,000 | 8,200 | 94% | 40·3% | 55·7% | 3% | 1% |
| 31 | 10,250,000 | 15,700 | 93% | 51·4% | 45·9% | 1·7% | 1% |
| April 8 | 11,500,000 | 11,200 | 98% | 31·6% | 55% | 3·4% | 10% |
| 14 | 13,800,000 | 11,400 | 100% | 22·4% | 66% | 0·4% | 11·2% |
| 15 | — | — | — | 31·3% | 56·7% | 3% | 9% |
| 17 | 12,400,000 | 10,200 | 98% | 25·6% | 67·1% | —* | 7·3% |
| 23 | 12,800,000 | 14,800 | 100% | 15·7% | 73% | — | 11·3% |
| 30 | 13,200,000 | 12,200 | 92% | — | — | — | — |
| May 9 | 13,700,000 | 8,600 | 93% | 6·6% | 84% | — | 9·4% |

Large number of anaplasmata (*vide* chap. v.) present.

* Included in the mononuclears.

The animal died from some unknown cause on May 27. Post-mortem, it was found to be quite fat and in good condition. There were no Balbiana in the œsophagus. Sarcocysts were found present in quantities varying from 5-20 per 15 milligrammes of muscle. The exact cause of the death in this case was not determined, as the animal had been dead for two days, and thus putrid before it was possible to examine it.

### Case 7. (March 1913.)

Half-bred ewe. Had been more or less under observation for some time. It showed very marked symptoms of the disease. As early as March, when one entered the field in which it was, one usually found it lying down. If one walked quietly up to it, it would allow itself to be caught without making any effort to get away. If one approached it with less caution, but yet slowly, at each step it would make an effort as if it were going to rise, but would lie down again. When, however, it was forced to rise it trotted away for about 10 yards ("cuddie trot"), with its head low down and held to the side. It would then either tumble precipitately over on its side, or it would stand with its head lowered, its ears set at a right angle to its head, its eyes staring fixedly (all evidences of conscious effort), the nostrils and muscles of face and body twitching and trembling, its legs bending beneath it. In this way it would gradually and slowly lower itself to the ground. Sometimes, however, it failed in this, and the last part of the procedure consisted in a sudden collapse and a rolling over on its side. While standing and while trotting its back was arched. In a journey of about 100 yards, which it was forced to make, it had lain down about ten times in 10 minutes. It only performed muscular effort when absolutely forced to do it. When resting on the ground it appeared quite comfortable, and the tremblings, so evident when the animal was standing, entirely disappeared. Its head was rubbed bare. It was constantly rubbing its sides on the fences. When its side was rubbed with the hand it turned its head toward the rubbed side, champed its jaws, and kept protruding and withdrawing its tongue.

After being forced to do a comparatively small amount of work it appeared to get very tired. Frightening it now, instead of making the animal run off, only made it shift from one foot to the other. If allowed to rest for some time, it ran off again quite briskly when frightened.

When trotting along, if its foot struck some inequality in the ground, it tumbled down in a heap. If laid on its back, its legs flapped about in a flail-like manner. When standing, and also when running, its hind legs were spread out. The intelligence was normal; there was no ataxia. The tendon reflexes were normal; when the legs, feet, &c., were pricked with a pin, the animal withdrew the part quite briskly. There were no muscle contractures. There was no limitation of any of the movements of the limbs. The electrical reactions of the muscles were normal. The pupils reacted to light. The tremor of the muscles was only present when the animal was

standing. Bladder and rectum were under complete control. There was no diarrhœa; the appetite was good.

Dr Edwin Bramwell, Assistant Physician, Royal Infirmary, Edinburgh, who very kindly examined this case for me, was of the opinion from the clinical evidence that the disease here was not one involving the central nervous system or the nerve trunks, and that the condition was either a primary muscle one, or was due to a general weakness of the animal.

The temperature on March 29 was 39·8° C., and on April 3, 40° C. The blood, examined on April 3, gave the count in Table VIII.

TABLE VIII.

| R.B.C. | W.B.C. | Hb. | Polymorphs. | Monos. | Eosin. |
|---|---|---|---|---|---|
| 11,200,000 | 14,000 | 76% | 47·5% | 52·3% | 0·2% |

Anaplasmata (*vide* chap. v.) were seen on the films.

The animal was killed with prussic acid on April 4. Post mortem findings :—

Hair rubbed off top of head; no wool rubbed off; no acari; subcutaneously, all along the back, little pockets, with loose fatty bodies in them.

Animal emaciated but not extremely so.

No gelatinous œdema of the muscles, or of fat of heart, omentum, or kidney.

No Balbiana in the œsophagus.

Very few filarial patches in the lungs.

One lamb in uterus.

A few strongyles in fourth stomach and a few sclerostomes in duodonem.

No acid-fast bacilli in intestines.

Chromaffin substance present in quantity in suprarenals.

No growth from heart blood or cerebrospinal fluid. No cells found in cerebrospinal fluid.

Cord, nerve trunks, and posterior root ganglia healthy when examined microscopically.

Every organ and tissue of the body examined microscopically in sections, and the only pathological finding of importance was the presence of enormous numbers of sarcosporidia in the striped muscles (see fig. 7), and the absence of the same from the non-striped muscles.

The following are the details of the examination of the muscles from various parts of the body by the 10 per cent acetic acid and Thionin blue method :—

*Hindquarters.*

| No. of piece. | Number of Sarcocysts per 15 milligrammes. |
|---|---|
| 1 | 20 |
| 2 | 110 |
| 3 | 70 |
| 4 | 76 |
| 5 | 63 |
| 6 | 50 |
| 7 | 90 |
| 8 | 110 |
| 9 | 32 |
| 10 | 50 |
| 11 | 33 |
| 12 | 44 |
| 13 | 10 |
| 14 | 110 |
| 15 | 159 |
| 16 | 60 |
| 17 | 24 |
| 18 | 49 |

*Œsophagus.*

| No. of piece. | Number of Sarcocysts per 15 milligrammes. |
|---|---|
| 1 | 25 |

*Heart.*

| | |
|---|---|
| 1 | 40 |

*Forequarters.*

| | |
|---|---|
| 1 | 30 |
| 2 | 90 |
| 3 | 33 |
| 4 | 36 |
| 5 | 15 |
| 6 | 98 |
| 7 | 45 |
| 8 | 40 |
| 9 | 39 |
| 10 | 24 |
| 11 | 40 |
| 12 | 29 |
| 13 | 50 |
| 14 | 28 |
| 15 | 35 |

CASE 8. (April 12, 1913.)

Two-year-old Cheviot tup. Received at the laboratory on April 12, 1913. When he first arrived (see fig. 8) he was in fair condition, and the wool was not rubbed off. When he was caught he became quite frantic—champing his jaws and shaking his head. If his sides were rubbed, he put his head to the ground, groaned, and snapped away with his jaws and ground his teeth until he was foaming at the mouth. He became very excited when approached. In spite of his previous timidity, if one released hold of him, meanwhile continuing the rubbing of his side, he could make no attempt to run away. He was very easily tired. After struggling for a very short time, he lay down panting, and could not be got to rise for at least ten minutes. Ate his food well. No diarrhœa; very thirsty; not getting much thinner. During the period of observation his weight remained steady at 92 lb.

*Temperature.*

Temperature, taken for a month at frequent intervals, varied between 39·5° C. and 40° C.

During the period while the animal was under observation the blood examinations in Table IX. were made:—

TABLE IX.

| | R.B.C. | W.B.C. | Hb. | Polymorphs. | Monos. | Eosin. |
|---|---|---|---|---|---|---|
| April | | | | | | |
| 14 | 8,200,000 | 11,000 | 72% | 25·4% | 70% | 4·4% |
| 15 | — | — | — | 27% | 66·3% | 6·7% |
| 17 | 8,000,000 | 11,600 | 78% | 9·6% | 88·1% | 2·3% |
| 22 | 10,000,000 | 9,800 | 72% | 23·5% | 73·5% | 3% |
| 30 | 7,900,000 | 7,000 | 67% | — | — | — |
| May | | | | | | |
| 8 | 6,850,000 | 10,000 | 60% | 23·7% | 76·2% | 0·1% |

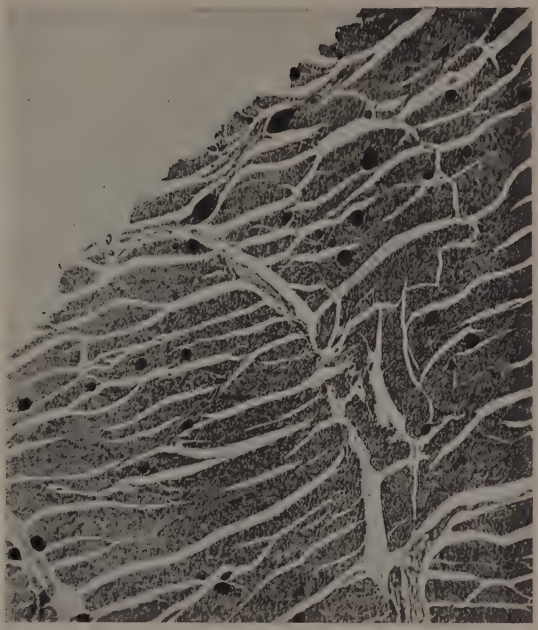

FIG. 7.—Section of skeletal muscle from Case 7, showing about 43 sarcocysts in one field ( × 50 *circa*).

FIG. 8.—Case 8. Cheviot Tup with Scrapie. No falling out of wool as yet. Note the characteristic attitude with the head low and held to the side, and the ears held out at right angles and slightly drooped.

He was killed by bleeding on May 13. It was noted, amongst other things then, that—

The wool was coming off on the side of the body and neck.
No acari were present.
Fair amount of subcutaneous fat.
A few worm patches in lungs.
Fair amount of fat on heart; no effusion into pericardium.
No Balbiana in œsophagus.
No growth in cultures from heart blood and cerebrospinal fluid.
No acid-fast bacilli found in intestine.
A few strongyles in fourth stomach.
A single sclerostome in duodenum.
Some tape-worm cysts in peritoneal cavity.
The suprarenals showed abundance of chromaffin substance.

All the tissues and organs of the body were examined in section. It has to be specially mentioned here that the male genitals were so treated. Nothing of importance was found anywhere except that the skeletal and heart muscles contained 10-20 sarcocysts per 15 milligrammes; while non-striped muscle in its various situations contained none.

### Case 9. (March 1913.)

Cheviot ewe from Northumberland. Very itchy and lean; sent up for examination. It died before many observations could be made on it. Its muscle contained >10 sarcocysts per 15 milligrammes. This was the only important pathological change found in this case.

### Case 10. (March 1913.)

Half-bred ewe, two-year-old. Very emaciated (see fig. 9). When lying down there is a difficulty in getting it to rise; when it does get up it goes a short distance and lies down again. "Cuddie trot" is present; very itchy; hair all rubbed off head and face; wool nearly all fallen off; appetite maintained; no diarrhœa; temperature 38·4° C. Had a lamb in April.

TABLE X.

*Blood.*

| | R.B.C. | W.B.C. | Hb. | Polymorphs. | Monos. | Eosin |
|---|---|---|---|---|---|---|
| May 6 | 5,250,000 | 8000 | 55% | 49% | 50·8% | 0·2% |

Some anaplasmata (*vide* chap. v.) seen.

On May 26 it was killed by bleeding. The following points were established at the port-mortem:—

Very little fat in the body muscles.
A few worm patches in the lungs.

A little fluid in the pericardium, and gelatinous œdema of the fat.
No Balbiana in the œsophagus.
Kidneys fatty degeneration.
No diminution of chromaffin substance of suprarenals.
A few strongyles in fourth stomach.
Four sclerostomes in small intestine.
A single tape-worm present.
Culture of heart blood and cerebrospinal fluid gave no growth.
No acid-fast organisms in intestines.
10-20 sarcocysts per 6 milligrammes of muscle.

### Case 11. (March 1913.)

Half-bred ewe, 2-3 years old. Very emaciated; no diarrhœa; taking its food well; hair rubbed off face and wool off sides and root of tail. When sides are rubbed, champing of jaws, &c., takes place.

Killed by bleeding on May 28. No growth obtained from heart blood or cerebrospinal fluid; no Balbiana; no acid-fasts present in intestine; only pathological finding of importance was the presence of 10-20 sarcocysts per 15 milligrammes of muscle.

### Case 12. (March 1913.

Cheviot ewe. Emaciated; no diarrhœa; hair rubbed off face and wool off sides; had been eating its food well. After a heavy fall of snow the animal was found dead on May 12. At the post-mortem the following facts among others of less importance were elicited:—

Acute pneumonic condition in the lungs, possibly the cause of death.
Liver, fatty degeneration.
No Balbiana in œsophagus.
No acid-fasts in intestine.
Chromaffin substance present in quantity in suprarenals.
Very lean, but no gelatinous degeneration of fat in muscles.
Ewe pregnant with twin lambs.
Udder examined microscopically without finding anything resembling a stage of sarcocyst.
5-12 sarcocysts present in each 15 milligrammes of muscle.

### Case 13. (March 1913.)

Cheviot ewe. Had been kept under observation for about five months. Had been eating its food well, but getting more and more emaciated. Very itchy; no diarrhœa; had a lamb in the spring.

Killed by bleeding on August 13, and post-mortem, among other things, the following were found:—

Hair rubbed off face, and wool rubbed off sides and root of tail.
Abscess on hind leg from rubbing.
One small fat-body-containing pocket on side.
No subcutaneous fat.
No dropsical gelatinous fat among the muscles.

FIG. 9.—Case 10. Half-bred Ewe in an advanced stage of the disease. Note the falling off of the wool and the emaciation. The animal is quite alert, however.

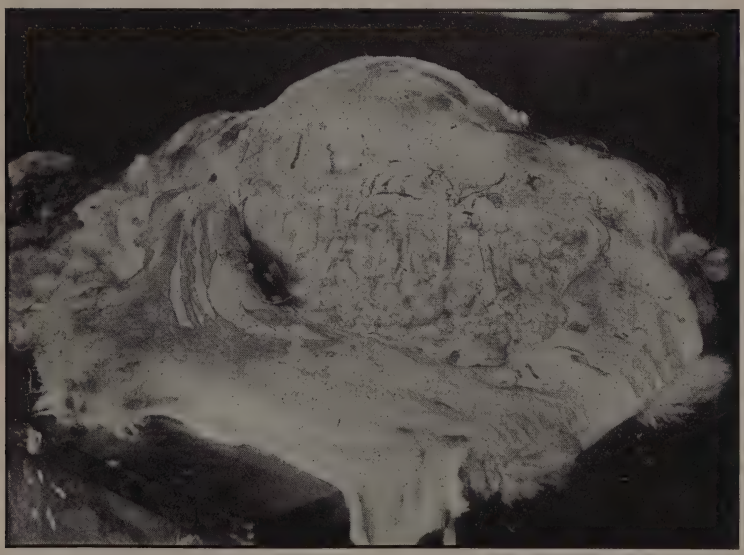

FIG. 10.—Case 14. Skin of side removed, showing extensive cavity containing rounded fatty bodies and having strands of fat crossing it. The two knives are in the continuation of the cavity forward, and the glass pipette is lying behind the atty strands.

No worm nodules in lungs.
Fat on surface of heart gelatinous.
No Balbiana in œsophagus.
No fat in mesentery or around kidney.
A few strongyles in fourth stomach.
One tape-worm cyst in abdomen.
A few tape-worms in small intestine.
No acid-fast bacilli in intestine.
Skeletal muscle contains 40-50 sarcocysts per 15 milligrammes.

### Case 14. (March 1913.)

Half-bred ewe, 2 years old. Getting thinner, although having a good appetite for the last five months; continually rubbing herself on fences; no diarrhœa; had a lamb in the spring.

Killed by bleeding on August 6. Post-mortem, there were found the following:—

Wool rubbed off face, sides of body, and root of tail.
Very emaciated.
Large cavity (see fig. 10) extending from tail to shoulder on the left side of the vertebral column, containing loose fatty bodies from the size of a pigeon's egg to that of a pea, and also having fatty (see fig. 11) strands running across the cavity, and fatty mammillary processes running into it. The cavity contained about a teaspoonful of blood-stained fluid.
At other places there were similar but much smaller cavities.
No gelatinous œdema of the muscles.
No Balbiana in the œsophagus.
A few small worm patches in the lung.
No fat in omentum or round the kidney.
No strongyles in fourth stomach.
A single tape-worm in intestine and a single tape-worm cyst in peritoneal cavity.
No acid-fast organisms in intestine.
Chromaffin substance present in quantity in suprarenals.
Spinal cord, nerve trunks, and posterior root ganglia appear normal.

Sarcocysts present in skeletal muscle and heart to number of about 90 per 15 milligrammes; none in alimentary tract (except in œsophagus), urino-genital tract, or udder.

### Case 15. (March 1913.)

Half-bred ewe, 2 years old. Had a lamb in the spring; had been kept under observation for the last four months; eating well, but getting thinner all the time; scratching and rubbing itself; no diarrhœa. Found dead, July 31. Post-mortem revealed the following facts, *inter alia*:—

No Balbiana in œsophagus.
No acid-fast bacilli in intestines.

Chromaffin substance present in suprarenals.
Udder showed nothing resembling a stage of the sarcocyst.
Skeletal muscle showed 40 sarcocysts per 15 milligrammes.

### Case 16. (March 1913.)

Half-bred sheep, 2 years old. Had been kept under observation for the last three months. Had a lamb in May, and after this developed an abscess in the udder. Has been getting very thin, in spite of the fact that it is eating its food well. Very itchy, hair and wool rubbed off face, sides of body, and legs; open sores on the hips and legs; no diarrhœa. Animal can hardly stand; when lying down it can be approached without its attempting to get up: if it does so, it usually gets halfway on to its legs and tumbles down again. It was killed on June 2, and post-mortem, *inter alia*, the following things were determined:—

Large amount of subcutaneous pocketing, especially along the ridge of the back where the skin is raised up by clear exudate. The subcutaneous tissues here are like a sponge.
No Balbiana in œsophagus.
No worm nodules in lung.
No strongyles in fourth stomach.
A single tape-worm in intestine.
A few sclerostomes in duodenum.
No acid-fast bacilli in intestines.

Skeletal muscle contains 10 sarcocysts per 15 milligrammes of muscle.
Nothing of note observed in any of the other tissues or organs.

### Case 17. (March 1913.)

Small Cheviot sheep, 2 years old. Been under observation for two months; getting thinner all the time; very itchy; no diarrhœa. Died May 31; post-mortem showed that—

The cause of death in this case was the distension of the first stomach, by a sodden mass of dense felted vegetable material resembling a wet peat; the stomach and intestines below this were empty.
The fat in the skeletal muscle was quite gelatinous.
The animal was emaciated.
There were no Balbiana in the œsophagus.
The lungs were healthy.

The skeletal muscle contained 10-20 sarcocysts per 15 milligrammes.

### Case 18. (March 1913.)

Half-bred ewe, two-year-old. Been under observation for two months; getting leaner all the time and rubbing constantly; stiff in

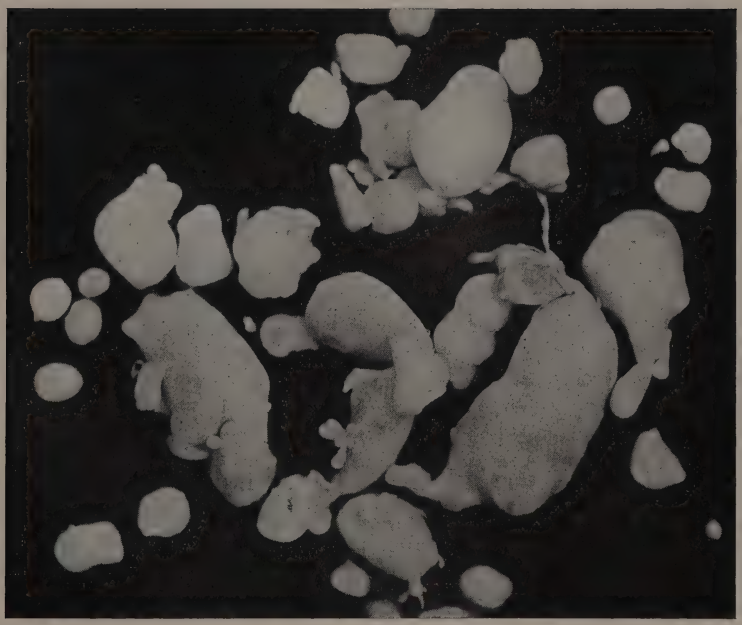

FIG. 11.—Some of the round fatty bodies from the cavity along the back of Case 14.

gait; no diarrhœa; sides of body and hips all rubbed. Killed by bleeding on May 28. Post-mortem there was found—

Fatty pockets subcutaneously along back and sides.
No Balbiana in œsophagus.
No worm nodules in lungs.
Chromaffin substance in suprarenals.
A few strongyles in fourth stomach.
A few sclerostomes in intestine.
No acid-fast organisms in intestine.
5-10 sarcocysts per 15 milligrammes of muscle.

### Case 19.

Border-Leicester gimmer from pedigreed stock. Had been noticed rubbing itself on fences. If caught, and sides rubbed, began to work its mouth, &c. Had given birth prematurely to two lambs the day before I saw it. Both lambs died. Was in excellent condition and very fat; no sign of disease except the rubbing, and by it the wool had been rubbed off the back of the body and the neck. There was no diarrhœa; no acari were present. Sarcocysts were present in the muscle to the number of 2-5 per 6 milligrammes (early case).

Another pure Border-Leicester gimmer from the same stock had died a few weeks previously with symptoms as above.

It would be well now to summarise briefly, chiefly with reference to the above cases, the main points in connection with the symptomatology and pathology of the disease. The main symptom, the earliest one observed and the most constant one is the itchiness. This itchiness varies, however, at different stages of the disease, and in some cases would appear to be absent throughout the disease.[1] In the very early stages of the disease when the animal as yet appears in the pink of condition and to the ordinary observer perfectly healthy, the disease can be diagnosed for a certainty by a fleeting, intermittent, and hardly noticeable shake of the tail or head. Such a case was Case 6, which afterwards developed into a frank example of the disease. A still later stage of the disease is exhibited by Case 19, where definite rubbing and loss of wool has taken place; and so on, the itchiness becoming more and more

[1] In this connection the separation of the disease by German authors into two entities—viz., "traber" (trotter), and "gnubber" (gnawer)—is of interest. The "traber" variety shows only muscular symptoms, the "gnubber" only itchiness. While, therefore, the itchy variety is not likely to be overlooked, sporadic cases of the trotting variety could quite well be missed. Hence the possibility that the disease may exist sporadically or otherwise in localities where its presence is not suspected (see also a similar separation of the disease by French authorities, pp. 27 and 28 *supra*).

marked until one reaches the condition exhibited by the Cheviot tup (No. 8) described above,—where the animal is shy, frightened, and begins to grind his teeth and champ his jaws if one even attempts to catch him. It is such a case as this that has given rise to the text-book description of the disease in Germany (*vide* May *supra*) as being one in which the animal is frightened and shy. Such cases are, however, in my experience, the exception, and the shyness would appear not to be psychic but to be due to the intense itchiness and the fear that they are going to be touched. This stage might be termed the first stage of the disease. The itchy condition may persist for a long time without the animal necessarily losing much weight or exhibiting any other symptom. Usually, however, in most of the cases a second stage is reached where emaciation and loss of muscle power are superadded to the itchy condition. Pathologically this augmentation of the symptoms is associated with a very great increase of the sarcocysts in the muscles. A condition of matters supervenes such as is described in Case 7.

Animals may die in stage 1 of the disease, possibly from the disease itself, more usually from complications. In my experience death most often takes place in stage 2, and even then usually from complications to which their weakened state has rendered them more liable. Sometimes, however, they die suddenly from heart failure, as in Case 3; at other times from asthenia after prolonged dropsy, &c. The skin conditions observed in the disease are secondary to the rubbing. A condition of great thirst is very noticeable in some of these cases. Diarrhœa was never observed. The appetite of the animal is preserved up to practically the very end. Rumination, however, appeared to be infrequent or absent. As regards the temperature of these cases, examinations made every second day for periods lasting over a month in some cases showed slight variations between the limits of 39° and 40° C.

With regard to the pathological conditions found in these cases, excepting for the moment the sarcosporidia, none were constantly present in all the sheep, or if present, are as often to be found in sheep not affected with scrapie. Instances of such conditions are the strongyles in the stomach, the sclerostomes in the duodenum, the tape-worms in the intestine,

and the worm patches in the lungs. The sarcosporidia, however, were present in every case, and *their numbers were proportional to the stage of the disease.*

The sarcocyst was never found by me in non-striped muscle.

The spinal cords, nerve trunks, and posterior root ganglia were examined in several cases, without, however, any abnormality being detected.

No acid-fast bacilli were observed in the intestine of any of the cases; nor was the mucous membrane of the intestine in any of the cases at all suggestive of Johne's disease.

While the large sarcosporidial cysts (Balbiana gigantea) are fairly often met with in sheep, it is curious to note that they were never observed in any of these scrapie sheep.

In all the cases where the examination was made, the chromaffin substance was present in quantity in the suprarenals.

The subcutaneous cavities, caused by the rubbing, and containing round fatty bodies, are of interest. In none of the cases was there any evidence of "scab" being present.

The gelatinous watery degeneration of the fat in the advanced cases in various situations of the body such as in the skeletal muscles, the auriculo-ventricular groove of the heart, the omentum, and perirenal tissue, and the peridural tissue of the spinal cord should be noted.

In several of the cases prolonged blood examinations were made, without, however, it being possible for one to decide whether there was any definite change in that tissue due to the disease. From the fact, however, that in some of the worst cases, *e.g.*, Case 6, the red blood count and the hæmoglobin percentage remained high, one might suppose that the disease of itself had little influence on the quality of the blood. An eosinophilia was present in some of the cases (Cases 6 and 8); but it is impossible to say whether this was due to the sarcocysts or to the roundworm infection which also existed in these cases. It is possible, too, that where an anæmia did exist, as in Case 4, this anæmia may have been due to a similar cause—strongyles in the stomach and sclerostomes in the intestine.

Nothing of the nature of a sarcocyst sickle or a possible derivative from such was ever seen in the blood. Anaplasmata were seen in several cases. Their significance, is discussed elsewhere (*vide* chap. v.).

As regards the duration of the disease, it is difficult to say how long the animals would last were it not that some intercurrent disease usually carries them off. They are reduced in condition by the disease, and fall an easy prey to infection or injury. Some writers have stated that the disease lasts longer in summer than in winter, and a contrary opinion has also been held. One would naturally expect that, owing to the more severe weather conditions in the winter, the disease would be of shorter duration. Personally I have known a case last more than five months. The data, however, are too few to go on, because a scrapie sheep is usually killed as soon as the disease is diagnosed. Yet I have heard it stated that scrapie sheep sometimes recover. This would be an important point, but one has no means at present of judging as to its truth. The only other point to be mentioned here is that the itching appears to be much worse during the hot summer months than during the winter.

Under the circumstances detailed in this chapter, we have to enquire whether the sarcocyst in the amount found in the muscles is sufficient to cause the symptoms, and the opinion to be elaborated in succeeding chapters is that it is.

# CHAPTER IV.

## ACCOUNT OF A CASE OF SCRAPIE SEEN IN GERMANY.

In furtherance of the investigations into Scrapie, I visited Germany in September 1913 to observe for myself possible cases of the disease existing there under the name of "Traberkrankheit." It was with the greatest difficulty and only by a remarkable piece of good fortune that I was able to see a case. This may in part be due to the disease not existing nowadays to such an extent as it did formerly, but it would appear to be mainly due to the great diminution in the number of sheep kept at the present day in Germany as compared with former times. On 10th January 1873 there were 19,666,794 sheep in Prussia (1), whereas on 1st December 1910 there were only 4,632,069. In Saxony in 1900 there were 835,711 sheep; in 1910 there were 200,151. It was in Saxony that I saw my one case, and Dr Raebiger, Superintendent of the Bacteriological Institute at Halle for the province of Saxony, said that this case and another which he had received within the preceding two months were the only cases of the disease he had seen in Saxony, and he has been in charge of the Institute there for a number of years.

Through the kindness of Dr Raebiger I not only had every facility to examine, photograph, and post-mortem the animal referred to above, but I also received a copy of the correspondence anent this case, a translation of which I give now.

Letter 1. From the owner of the sheep to the Bacteriological Institute, Halle, dated 27.5.13.

For years I have had a disease among my sheep which appears in the following way: It begins with an irritation of the skin. They rub themselves first at the tail and the head. They like to get at every wall and hurdle and rub backwards and forwards till the wool falls off. Little by little the entire wool of the hind

legs and head goes. Later, they become stiff in the legs and get worse until at the end of half a year they can no longer stand erect. The appetite continues to the end. In spite of all their eating the animals become thinner from day to day. Different veterinary surgeons have been at them already and could find nothing. After much search in veterinary books, I regard the disease as the "trotting disease." I lost fifty ewes about four years ago. During the last few years it has appeared less frequently, and I hoped that it was abating, but now suddenly five more cases have appeared. "Inbreeding" is excluded. Each year I have bought new rams from the most famous breeds, and all of them mostly died after one tupping season. I intend now to send you a living animal for observation, and ask whether I can do this at any time. . . .

Letter 2. From Same to Same. 6.6.13.

. . . I send to you to-day, as I regard any danger of infection as impossible, one ram and one sheep in a crate. The ram has been ill for three months and the sheep for eight to fourteen days. Till now the animals have taken their food as usual. They have become, however, as I mentioned to you before, thinner from day to day. *My observations make me think that this disease is spread only by breeding. I do not believe that it is spread by daily association at pasture.* It appears, further, as though the disease were more prevalent in very dry years. [Italics mine.—J. P. M'G.]

Not one of the sheep which I bought two years ago has died. I want now to get rid of the whole of my fine stock and buy in new breeding material. I have bought rams each year, and these have always died with me. The ram sent by me to-day is of my own breeding. He has only tupped a few ewes, and has been used otherwise as a "chaser." "Inbreeding" does not exist.

Letter 3. From Same to Same. 25.6.13.

Your letter No. 1682 to hand. You inform me that the ram I sent you is dead of pneumonia and pleurisy. Now I would like to know if it is possible that the animal had been already sick for three months, for it has been off-colour for this length of time—that is to say, it appeared ill and its wool fell off. In spite of this, however, it took its food quite well. Did you notice that it suffered from a skin irritation and rubbed itself continuously on the paling and wall? If one touched it on the tail, it twisted itself about and faced round. In this way the suspected disease has always at first shown itself. The animals appear otherwise quite lively, eat well, but in spite of this grow thinner from day to day. I ask you to weigh them now and again. I have mentioned already that it sometimes lasts half a year before the animal dies. I have now made a last trial, and have bought a new set of ewes and got rid of the old. If after this things do not improve I shall have to give up sheep-breeding, much as I regret it.

Fig. 12.—Merino Ewe (referred to in text) suffering from Traberkrankheit. Note the general attitude, and especially the spread out hind legs.

Fig. 13.—Same as in Fig. 12. Note the attitude.

Letter 4. From Same to Same. 9.9.13.

Your letter of 8th of last month to hand. I submit to you the following information. It may be assumed with certainty that the disease was introduced by bought-in tups, yet it is not proved by which ram or in what year this happened. After the disease assumed alarming proportions, I always tried by immediate slaughter and extirpation of the progeny of diseased animals to put an end to the condition. This has partly succeeded, in so far that for the last two or three years so many diseased animals have not been noticed. Last year it became worse. It can further be assumed that the disease is only propagated through the sexual act. *Where contact of sick and healthy animals exists the latter do not become infected.* A special age of the animal in which it is most easily infected has not been observed. The disease, however, has mostly started with the *two-year-old* animals, and this may be looked upon as a proof that the infection results from procreation. *During the first years of the disease only females were affected with the disease;* later, also some breeding rams have succumbed. Quite a number of diseased and also dead animals have been examined by different veterinary surgeons and nothing has been found. The last ram which I killed because it was getting daily thinner was examined by the local veterinary inspector, and as nothing definite was found wrong with it, the carcase was passed for human consumption. By extirpation on a large scale only fifty animals of my own breeding are left, and by laying in a fresh stock I hope that I have overcome the disease. At the present moment my whole stock is without blemish. [Italics mine.—J. P. M'G.]

The diseased sheep seen at the Bacteriological Institute at Halle was the ewe referred to in the above correspondence. On the 6th of June it had only been noticed ailing for about a fortnight. I saw it first on Friday, 5th of September. It was a Merino sheep, between two and three years old. It was decidedly thin but not absolutely emaciated. At no part of the skin was there any wool rubbed off; nor was there any sign of any biting insects or any eruption on the skin. If the animal was caught and its sides pinched or rubbed lightly, it made no attempt to get away, but turned round its head and kept champing its jaws in the most energetic manner (see fig. 15). The animal was not in the slightest degree shy; nor was it dull and moping; on the contrary, it moved about investigating with its nose anything that took its fancy. Its movements, however, were very slow, stiff, and deliberate. When standing still, and even when undisturbed, a fine tremor could be seen over the whole body. This was very marked indeed. When forced to

move quickly the animal could not gallop like a normal sheep, but trotted, throwing its legs high the while (see fig. 14). When standing at rest its hind legs were spread out on a broad base (see figs. 12 and 13). It frequently scratched itself with its hind feet, and rubbed itself against the palings of the enclosure even when standing only a few feet away from the observer. It took its food well. There was no diarrhœa. Temperature was normal. If made to run much the animal soon became exhausted. It appeared to be in an advanced but not in the final stage of the disease.

It was killed by bleeding from the throat on September 11. There were no eruptions on the skin, no "keds"[1] among the wool, no bare patches on the head or elsewhere. Subcutaneously, there was a fair amount of fat present, and there were no subcutaneous abscesses or cavities with masses of altered fat. The muscles were not gelatinously changed. The lungs were healthy, not even showing filariasis. There was no effusion into the pleura or pericardium; the heart was healthy, and the fat present of a normal appearance. The thymus was absent. The trachea, thyroid, glottis, &c., were healthy. In the abdomen there was no excess of fluid; there was a considerable amount of fat in the omentum and round the kidneys. This was normal in colour and not gelatinously degenerated. To the naked eye, the liver, spleen, kidneys, pancreas, suprarenals, gall bladder, bladder, uterus, and adnexæ appeared healthy. As regards the alimentary canal, there were no sarcosporidial cysts (Balbiana) in the wall of the œsophagus; no strongyles in 4th stomach; and no parasitic worms in the rest of the intestine. Diarrhœa was absent, well-formed fæcal pellets being present in the colon. The whole of the alimentary canal appeared healthy; smears were made from the ileum, the jejunum, and the large intestine, but no acid-fast bacilli were found. (I am indebted to Dr Raebiger for this observation, as also for the notes on the presence or absence of parasites.)

Pieces of the following organs were fixed in formalin, and examined later microscopically: lung, lymph-gland along lower end of œsophagus, thyroid, heart, tongue, liver, spleen, suprarenals, kidney, pancreas, uterus, gall bladder, bladder,

[1] Melophagus ovinus.

Fig. 14.—Same as in Fig. 12: showing the animal trotting.

Fig. 15.—Same as in Fig. 12: showing the animal reacting to its skin being pinched.

4th stomach, rectum, small intestine. With the exception of the presence of sarcocysts in the heart muscle nothing abnormal was found. Part of the lumbar cord, the lumbar posterior root ganglia, and the sciatic nerves were examined similarly and found normal. Several pieces of muscle were removed from the abdominal wall, hind legs, diaphragm, psoas, lumbar muscles, pectorals, muscles of fore leg, neck, and jaw. These, about thirty pieces in all, were examined in the method noted at the beginning of chapter x., and in every piece of muscle, sarcocysts to the number of 10-20 per 10-15 mgms. were found.

In concluding this chapter, it would seem unnecessary to say that we are dealing with a case of disease identical with scrapie. The only pathological finding to be recorded in this case is the marked presence of the sarcocyst in the muscles. Filaria of the lung and strongyles of the 4th stomach, parasites almost universally present in sheep above one year old in this country were here absent. Attention may be directed with advantage to some points in the correspondence mentioned above. It will be seen that the view is strongly urged that the disease is *not* contagious, but that it is spread only by breeding. The writer appears to favour the view, moreover, that the tups spread the disease, but this would appear to be only an assumption on his part, for he says (*vide supra*), "It may be *assumed with certainty* that the disease was introduced by bought-in tups, yet it is not proved by which ram or in what year this happened"; and he makes the further statement which would appear to annul this assumption—namely, "*during the first years of the disease only females were affected.*" It will be seen later that the evidence for tups spreading the disease in Scotland is of a similarly inconclusive nature. Another point to be noted in the above letters is the method employed for getting rid of the disease, and this should be compared with a somewhat similar method in vogue in Scotland—viz., extirpation of the diseased flock and replacement by healthy animals.

REFERENCES. Chapter IV.

(1) Landwirtschaftlich Wochenschrift für die Provinz Sachsen. No. 4. 1912.

# CHAPTER V.

## THE STRUCTURE AND POSSIBLE DEVELOPMENTAL STAGES OF THE SARCOCYST AND THEIR RELATION TO THE SPREAD OF THE DISEASE.

INFECTION with sarcocysts such as those described in the muscles of scrapie sheep is comparatively common amongst the higher animals. The condition has been recognised in the pig, the ox, the camel, the sheep, the goat, the horse, mouse, rat, deer, dog, cat, rabbit, monkey, buffalo, kangaroo, &c., &c. It has also been found in man and in certain birds. The sarcocyst as it appears in the muscle is probably a stage in the development of a lowly organised animal form, the full life-history of which is as yet unknown. Under a low power of the microscope it appears as an elongated cigar-shaped body, a minute fraction of an inch in length, situated inside this muscle fibre (see fig. 25).

In this chapter the minute histology of the sarcosporidial cyst and its elements will not be dealt with exhaustively. The object will be rather to bring into prominence certain facts which have been observed and which may have a bearing on the question of the propagation of the parasite.

In the sarcosporidial cyst, when fully developed, there exists on its outer side a cuticle covered with cilia which penetrate the substance of the muscle fibre. This cuticle, according to some, is traversed by fine pores, and according to others (Bertram) shows fine clefts. These pores and clefts are very minute, and neither are of such a size as to give one the idea that a body of the size of the sarcosporidial sickle could pass through them. Inside this cuticle, and lining it, is a row of cells (sporoblasts), which by undergoing division give rise, in a region nearer the centre of the cyst, at first to immature sickles and later to ripe ones. Still nearer the centre the


FIG. 16.—Shows the stages occurring in the setting free of the granules when the sickles are placed in 1 per cent glucose solution in water at room temperature: *a* normal sickle; *b*, *c*, *d*, *e*, and *f* show changes in shape and size; *g* and *h* components into which *f* resolves—*g*=capsules, *h*=granules and residual protoplasm. (Drawing by Mr Muir.)

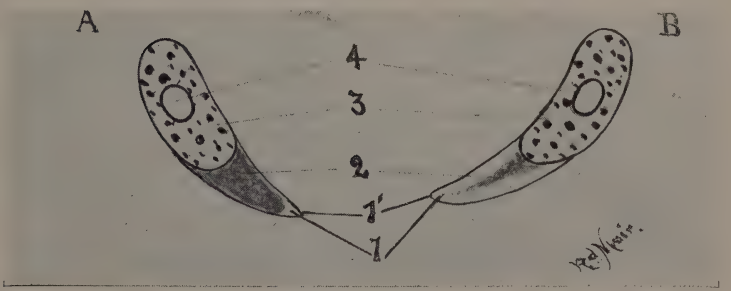


FIG. 17. Minute anatomy of sarcosporidial sickle. *A* normal, *B* with polar capsule shrunk; showing capsule with (1) space between capsule and polar capsule, (2) polar capsule, (3) protoplasm of sickle with chromatic granules, and (4) nucleus from which chromatin has wandered.

sickles appear to be degenerated, and have lost their chromatin material.

Various opinions have been held regarding the significance of these sickles. Laveran and Mesnil (1), for instance, express themselves as follows: "If the spore of the sarcocyst is morphologically comparable to that of the myxosporidia, it is not so physiologically. Its relative fragility, the action of water on it, &c., appear to indicate that it does not represent the form under which the parasite preserves itself in the outer world." Again, Negri (2), Fiebiger (quoted from Minchin[1]), V. Betegh (3), and Teichmann (4), believe that the so-called spores of the sarcocyst of the mouse, horse, and sheep, reproduce themselves by fission, and so are not spores in reality.

The examination of this last statement necessitates some reference to the minute histology of the sickle. Many different views are held on this subject, most of the variations of opinion having reference to the actual existence and position of the polar capsule. The diversity of opinion as regards this organ is so great that some authorities, such as Perrier (5), Teichmann (*op. cit.*), and Alexieff (6), deny its existence altogether. The comparative merits of the various views will not be discussed here, but one's own observations on the subject will be given as follows.[2] Motility would appear to be absent in the sarcocyst sickles at room temperature or at 37° C. The media in which they were observed by me were saline, ascitic fluid, and 1 per cent glucose water.

If sickles be emulsified in a 10 per cent acetic acid solution deeply tinged with Thionin blue, a number of important points can be observed. In the first place it will be seen that a *definite capsule* surrounds the protoplasm of the sickle. It can be seen even in unstained preparations, but in preparations made by the method just described the unstained hyaline capsule is easily seen by contrast with the stained protoplasm of the parasite. Especially is this so at the sharp end of the sickle—the end away from what one may term the nuclear or blunt end—where a V-shaped space is left between the rounded end of the protoplasm and the capsule. This

[1] 'An Introduction to the Study of the Protozoa.' London, Arnold. 1912.

[2] I am indebted to Mr Henderson, M.R.C.V.S., for his kindness in supplying me with the material used for this part of the investigation.

capsule, too, is brought into evidence by the changes which the sickle undergoes in 1 per cent glucose water, to be afterwards described. Again, if the contents of a ripe cyst are examined fresh, these capsules, now round in shape and empty, can be seen. They are present also in large numbers in the glucose water preparation mentioned above, having extruded their protoplasmic contents.

As regards the protoplasm of the sickle itself observation leads one to the following views on the subject (see fig. 17A). The number ($I^1$) refers to the capsule, and 1 indicates the V-shaped space between the capsule and the protoplasm of the parasite. The sickle has a sharp end and a blunt or nuclear end. The number 4 refers to the nucleus, which remains uncoloured practically when the preparation is treated with dyes. Surrounding 4 is a zone indicated by 3, which contains a very large number of chromatic granules, some of fairly large size. Situated nearer the sharp end of the sickle, and apparently definitely differentiated and delimited from zone 3, is a zone 2 which contains no granules.

If one examines the contents of a *ripe* cyst in saline under a high power of the microscope, sickles are observed as just described, with empty nucleus, a zone indicated by number 3 filled with granules, and zone 2 devoid of them, the whole being surrounded by a capsule. One also sees very numerous small granules about 1 $\mu$ in size scattered all over the field; empty sickle capsules now rounded in shape; and pieces of vacuolated material, some containing small granules, some emptied of these.

Such appearances, though easily found in a fresh preparation in saline, can be much more easily seen by making the emulsion in 1 per cent glucose water and keeping it at room temperature for about three hours. Then one sees that every sickle practically has undergone a change. Fig. 16 gives a rough idea of how this evolution takes place: *a* shows a ripe normal sickle; *b* shows slight enlargement of this; *c* shows a slight bulge ("fish embryo" appearance) on the concave side of the sickle, which is filled with a material containing no granules, at least until the bulge becomes very large. The bulge gets larger, the nuclear spot becomes indistinguishable, the sickle swells, the granules appear to multiply and get larger, and the protoplasm becomes very

## DESCRIPTIVE MATTER TO FIGS. 18-23.

The preparations from which these photographs were made were fixed wet in alcohol and stained with Leishman. Figs. 18 and 19 are from fresh cysts from the œsophagus of the sheep ; the rest are from such cysts after incubation at room temperature in 1 per cent glucose water for some time. In Fig. 18 ( × 1000) is shown the typical crescentic shape and the presence of a large number of granules. Fig. 19 shows the same condition but under a magnification of 2000. Fig. 20 ( × 1000), a glucose water preparation, shows the increase in size, change in shape, as compared with Fig. 18, and the presence of a larger number of free granules. "Fish embryo" forms are very common. Figs. 21, 22, and 23 show the same under a magnification of 2000. Note in Fig. 21 two stages (earlier) with the tips of the crescent still pointing forwards towards the bulge, and one with the tips pointing backwards ; in Fig. 22, that all have their tips pointing backwards ; the large number of granules in them and the large number of free granules (mostly out of focus) ; in Fig. 23, one cell of the rounded form with the granules escaping, and the other of the "fish embryo" type with tips of crescent back and the capsule shown.

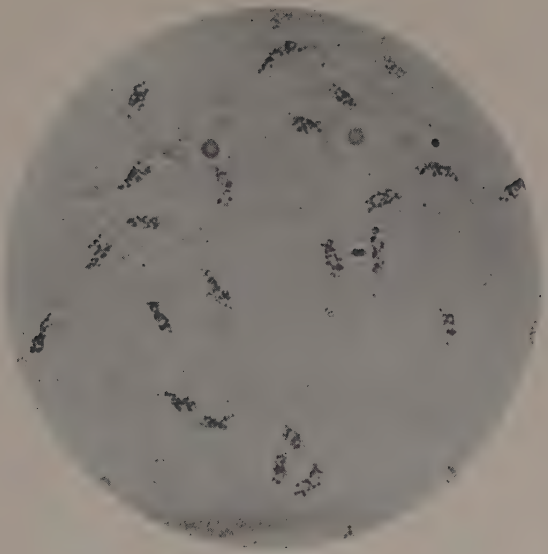

Fig. 18.

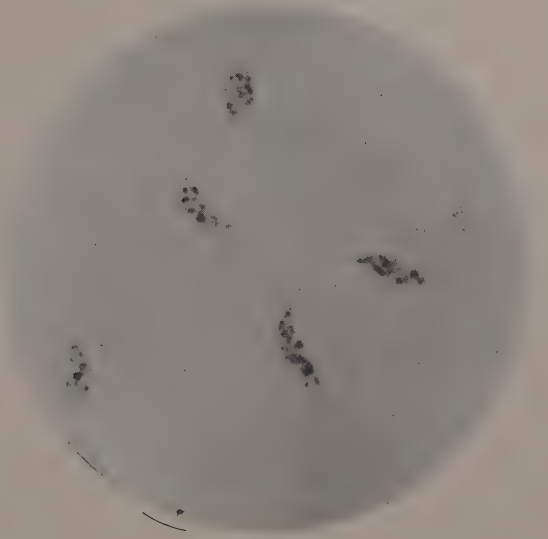

Fig. 19.

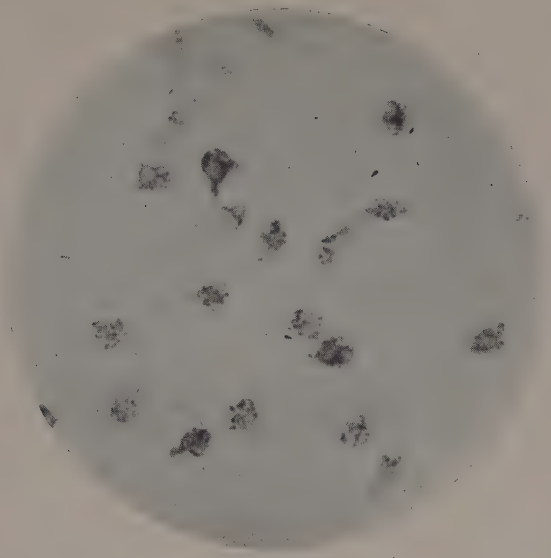

FIG. 20.

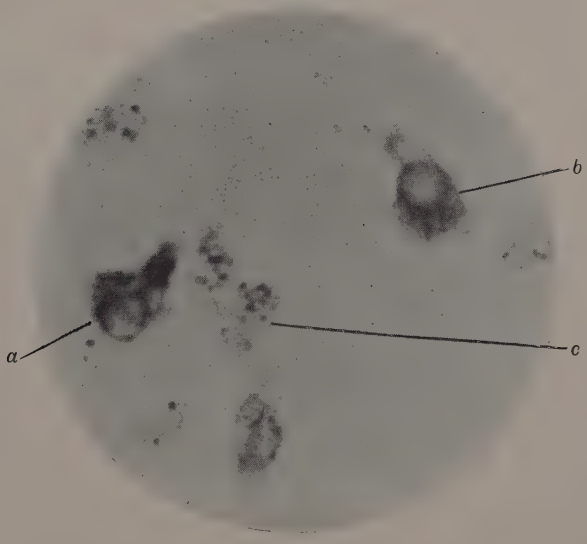


FIG. 21.

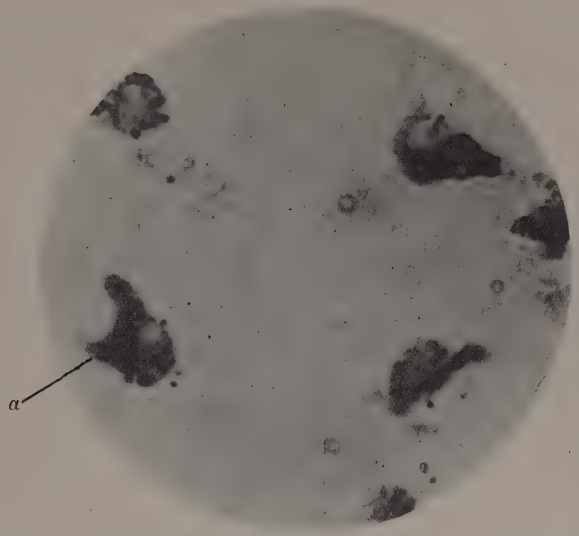


Fig. 22.

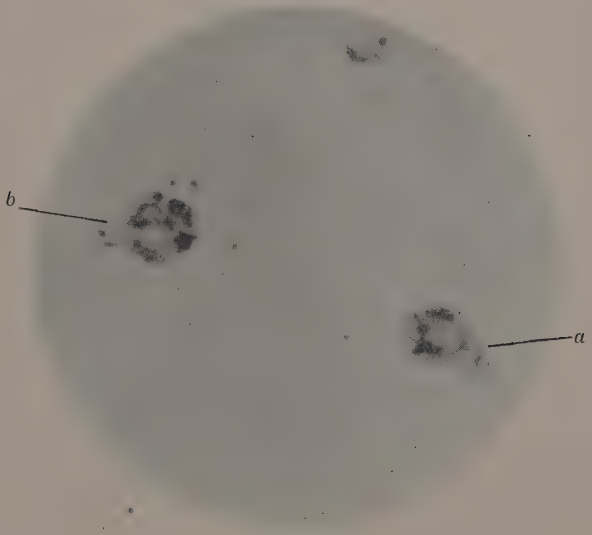


Fig. 23.

vacuolated and the concavity of the sickle appears in the opposite direction, until finally a rounded form is reached at the stage indicated by *f*. The cyst then bursts, giving rise to an empty round sheath *g*, and a mass of vacuolated material containing a large number of granules. This latter mass disintegrates into free granules and *débris* as in *h*. These granules appear to me to be the final development of the sickle which produces new infections. (See also photographs illustrative of these points, where in fig. 21 *b* and *c* correspond to *c* and *d* of fig. 16; and *a* in figs. 21 and 22 represent stage *e* there; stages *f* and *h* are seen in figs. 22 and 23, *h* being represented especially by *b* in fig. 23. *a* in fig. 23 shows the presence of the capsule. This is also seen in some of the other photographs.)

Returning now to a consideration of the ripe sickle, as seen in fig. 17 A, the nucleus (number 4), as seen in unstained and stained preparations, is an oval sharply delimited vacuole empty of chromatic material. The region 3 is filled with chromatic granules. These appear to be derived from the chromatic material of the nucleus, which has wandered out; 2, a region containing no granules and definitely delimited from 3, would appear to be an instrument which, by swelling out under certain conditions, mechanically ruptures the capsule and sets free the mass (3) containing the granules. Its teleological signficance is therefore apparently a mechanical one and in a line with that of a polar capsule. That it is separate and distinct from the rest of the protoplasm inside the capsule may also be inferred from what happens to it sometimes when the sickles are kept in ascitic fluid. The part 3 remains quite distinct and unaltered, but this part shrivels up and gives the appearance shown in fig. 17 B. The polar capsule is shrivelled up, and the capsule 1 is well seen. The nucleus 4 may or may not be evident.

With reference to the opinion expressed above by Negri, Fiebiger, V. Betegh, and Teichmann (*q.v.*), that the spore of the sarcocyst does divide, while this may be true of an immature sickle-shaped cell, if such exists, it would seem impossible to be so in the case of a fully-developed spore surrounded by a capsule.

Recognising the fact that mice can be infected by eating infected meat, it appeared possible that intermediate stages of

the parasite would be found in the intestinal canal of mice fed for this purpose. Several mice were therefore fed on heavily-infected meat, and killed at various times after feeding and the intestinal contents examined. No insight, however, into the development of the sarcocyst was derived from such experiments.

It may be further mentioned that attempts have been made by me to cultivate the sarcocyst in various media at different temperatures, aerobically and anaerobically. Media used were broth, blood broth, ascitic fluid, ascitic fluid with fresh tissue, 1 per cent glucose water, and 1 per cent glucose ascitic fluid. In all the media, with the exception of those containing glucose, the sickles either remained unchanged or degenerated. The changes in the glucose media have been described above; these would appear to be rather an accentuation of a normal process for setting free the granules inside the muscle cyst than an actual cultivation of the sarcocyst.

It would be well to notice here attempts by others to grow the sarcocyst and their results. Piana (quoted by Janin (7)) left Balbiana isolated from a muscular tissue in sterilised capsules with a little sterile water or gelatine prepared with *Fucus crispus* according to the method of Celli and Fiocca for the culture of amœbæ. The falciform corpuscles decomposed and set at liberty little hyaline globules, which gradually increased in volume and acquired a contractile nucleus. They took amœboid forms, were motile for several days, then encysted and underwent a true encapsulation and entered into a state of latency. He observed these phenomena to take place in a space of twenty-five to sixty days. Erdmann (8) notes, after feeding a mouse on sheep sarcosporidia, the presence of small round bodies in the lumen of the gut. Little reliance can, however, from its very nature, be placed on such an observation. Balfour, 1913, (9), made cultures in Nicolle's medium and in broth of a sarcosporidial cyst found in an antelope. In both sets of cultures he found a number of small hyaline spherical bodies, many of which contained a dark motile granule. He thought these might be young spores or even amœbulæ derived from them.

Having followed the development of the sarcocyst to this stage it must now be asked if there are any observations


FIG. 24.—From V. Betegh and Dorcich's paper (Cent. f. Bakt., Abt. 1, Orig. Bd. 63, p. 388), illustrating the development of the sarcosporidium in the musculature of the duck's stomach. The dimensions of figure 1 are 3·6$\mu$ broad by 4$\mu$ long.

bridging over the gap between the small bodies described above and the sarcocyst in the muscle as we usually find it. These stages, if they exist, would presumably be very small and difficult to find; and one knows how easy it is to examine muscle from a sheep which will almost certainly later develop sarcosporidia in large numbers without, at the time of examination, finding any. There are observations, however, which enable us to connect up these small forms with the early stages of infection of muscle. Van Betegh and Dorcich (10) fed ducks on sheep sarcosporidia, and found a development of the sarcosporidia in the muscle of the stomach. These early stages were very small, and measured 4 $\mu$ long $\times$ 3·6 $\mu$ broad, although they consisted of three chromatin elements, each surrounded by its mass of protoplasm. Thus each chromatin particle is of about the dimensions of the granules shed from the burst sickle. (See fig. 24.)

As regards the migrating power of these small chromatin bodies, if it is possible for them to wander through from the stomach of the duck into the musculature of the duck's stomach, one would suppose it would be an easy matter for them to travel from a sarcosporidial cyst—through the pores if they exist, or from a burst cyst—to any part of the body. There is nothing improbable, then, in their wandering through to a fœtus *in utero*, and, although their small size at first prevents their discovery, eventually when they have grown they can be observed. Such an occurrence would explain the congenital infectiousness of the condition in the experiment to be detailed in chapter ix.

At one time (11) I thought it possible that the anaplasmata of the red blood cells might be these chromatin dots journeying towards a muscle fibre. Further consideration has caused me to modify this opinion, and I now believe that while some of these anaplasmata may be of this nature, all certainly are not. Many of them are, as may be proved by the vital staining method, a local concentration of the material which, when diffused, gives the appearance of polychromasia. Others of them may be of quite another origin. The appearance of the anaplasmata in the blood of the animals after the introduction of the sarcosporidial flesh, described by me in the paper just referred to, seems to me now either to have been due

to the operation *per se* or to have been an evidence of the action of the toxin of the sarcocyst.

To summarise this chapter, I have enunciated the view that these chromatin granules play an important part in the transmission of the disease, both in the endogenous and exogenous spread.

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(1) Laveran and Mesnil. C. R. Soc. Biol. 1899. p. 245.
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# CHAPTER VI.

## SYMPTOMS EXHIBITED BY ANIMALS HEAVILY INFECTED WITH SARCOSPORIDIA.

It would be well to preface this chapter by the statement that symptoms referable to macroscopic sarcosporidial tumours (Balbiana) in the œsophagus or elsewhere of sheep or other animals are not being considered here. Such a discussion would appear, moreover, to be alien to the subject, as there has never been found in any of my cases of scrapie, in any situation, such macroscopic tumours. When this reservation is made, there are comparatively few instances, in the literature, where symptoms have been observed during the life, of an animal found post-mortem to have its muscles heavily infected with microscopical sarcosporidia. This is not to be wondered at, as there is nothing to the naked eye to indicate the advanced pathological changes which one finds microscopically in such cases.

The discussion of the subject of this chapter might be appropriately begun by a quotation from Janin (1). At the foot of page 254 he states:—

> In spite of these figures [statistics of sarcosporidia in sheep] it should be difficult to admit the absolute harmlessness of sarcosporidia, if we call to mind what we know to-day of their evolution in the tissues and of the elaboration by them of a toxic principle. Their presence can, without doubt, remain for a long time unperceived, although the muscles ought to lose in time their elasticity and normal pliability; but it appears illogical that their appearance in great numbers in the important organs, such as the heart in particular, is incapable of causing mechanical troubles apart from parenchymatous and fatty degeneration capable of causing death. On the other hand, if the toxin elaborated by the sporozoites, the sarcocystin, does not kill the animal, has it not, *a priori*, as all toxic substances, an unfavourable action on the nutrition? *In the œdemas, the emacia-*

*tion, the cachexia, in all these so often concomitant phenomena, ought the toxin not to be taken into consideration?* [Italics mine.—J. P. M'G.]

This is a statement by one who has had considerable experience of sarcosporidiosis in sheep, and the last sentence should be carefully noted, especially in the suggestion made that a toxin may be concerned in producing symptoms frequently present in sarcosporidiosis.

Moulé (2), page 125, in 1886, made some observations on the presence of sarcocysts in the muscles of sheep in France, which are of great value. He states as follows:—

Since the first of February 1886 I have examined the muscles of more than 150 sheep, and have found psorosperms in about 120 of them. This leads me to affirm that the sheep, of all animals, is the one which harbours most often sarcosporidia. The most of my observations were carried out on cachectic sheep seized at meat auctions. [He thus had no opportunity of observing the symptoms during life.—J. P. M'G.] I examined with the microscope 100 samples, taken from 100 different sheep, from different parts of the body, as follows:—

1 from the fleshy part of the diaphragm.
6 „ „ muscles of the thigh.
93 „ „ muscles of the shoulder.

With the exception of a single case, I have found psorosperms in more or less considerable quantity in all the samples taken, whether from cachectic lambs or sheep. My preparations have been of the simplest. I have always limited myself to taking, by means of fine scissors, a specimen of muscle like a thread, and crushing it between two slides of glass. In general, one preparation sufficed, and it was only in very rare cases (8 in all) that I had recourse to 2, 3, 4, or 5 preparations to discover these parasites.

In 100 cachectic sheep examined, 99 presented psorosperms, distributed as follows:—

| | |
|---|---|
| Prodigious quantity—*i.e.*, 5, 6, and sometimes more, in a field of the microscope in . . . . | 14 sheep. |
| Many—4 or 5—in the preparation in . . . . | 50 „ |
| Quite a number—a few less than in the preceding case—in . . . . . | 12 „ |
| A few—one or two in the whole preparation and in one preparation in . . . . . | 17 „ |
| One in 3, 4, or 5 preparations in . . . . | 5 „ |
| 2 in 25 preparations in . . . . . | 1 „ |
| | 99 |

Usually the psorosperms exist in the degree "many" in sheep whose flesh is strongly infiltrated—"soaked" in butchers' language; whilst, on the contrary, they are present in small quantities in sheep whose flesh presents little alteration.

I was quite surprised when, at my eighty-third examination, I met with a want of success, especially after I had failed to find the parasite after twenty successive preparations, whilst the lamb was in a state of extreme emaciation. All the organs—the spleen, the kidneys, the lungs — were healthy, and the liver did not contain any flukes. But after a careful examination I discovered in the thoracic cavity, at the articulation of the ribs with the vertebræ, an abscess of the volume of a nut which was without doubt the cause of the emaciation. I must admit, however, that in a sheep bearing the number eighty-seven, I found only two psorosperms in twenty-five preparations, and these appeared young and scarcely formed. I could find nothing in the condition of the animal to account for this want of success.

As a means of control I carried on investigations on fifty-one sheep of good quality, chosen from among the fattest. The samples were taken a little everywhere where that was possible without damaging the carcase.

| | | |
|---|---|---|
| 10 | from the muscles of the | neck. |
| 23 | „ „ | shoulder. |
| 8 | „ „ | thigh. |
| 7 | „ „ | abdomen. |
| 3 | „ „ | diaphragm. |

In these fifty-one samples several were taken from sheep of the first quality of Austrian origin ; four only were taken from animals sick, though very fat, of which three were from sheep affected with flatulence and one with anthrax.

The results have been far from being the same as in the cachectic sheep, for of the fifty-one examined I have found the psorosperms only thirty-one times, and yet it has been necessary to make numerous preparations—not less than five, and often even ten—to determine the presence or absence of these parasites, as they are much rarer, much smaller, and less well formed than in the muscular tissue of cachectic sheep. The psorosperms were present in the anthrax sheep, while in the thirty other positive cases they were distributed as follows:—

| | | |
|---|---|---|
| Several in . . . . . | 5 | sheep |
| 1 or 2 in less than 5 preparations in | 10 | „ |
| 1 or 2 in more „ | 15 | „ |

At page 128 he makes the following statements with regard to finding them in other animals:—

Of twelve lean goats, psorosperms were found only in three. In these they were few in number, one in three or even seven preparations. In the ox, of eight animals seized for emaciation, three only had psorosperms, one in five preparations. These parasites have only been found once in eight sick oxen.

In the horse, of eight lean ones several psorosperms were found in two,—one in ten preparations in one, and nothing in four. There was at the same time no trace of parasites in six fat or half-fat horses. In the pig, of nine animals examined, nothing was found in eight; one

only, in which the flesh was strongly infiltrated, showed larger but less numerous sarcocysts than in the sheep.

Again he states (page 694), with regard to their frequency in the ox:—

In forty-three specimens of muscle taken from forty-three different oxen in good condition, I have found psorosperms only three times, and they were in small quantity (one or two in ten preparations). In lean oxen these parasites are much more frequent, although, however, the percentage obtained has been much less than that obtained in cachectic sheep. In this series I have examined only lean oxen seized for extreme emaciation, in which the fat was deficient, so to speak, and in which the muscles for the most part were infiltrated with a more or less abundant dropsy. Of the ninety-four animals of this series I have found psorosperms in thirty-four of them, and yet it must be added that these parasites do not exist there in great numbers, for I can cite only eight cases with the degree "many" or "several." Among the twenty-six others, one found with difficulty one or two psorosperms in ten preparations. It is then among the lean oxen, as among the cachectic sheep, that one finds these parasites most often.

Moulé's statistics here given are very valuable, for cognisance is taken not only of the presence of the sarcosporidia (a relatively unimportant fact), but also of their number and their variation in number with the clinical condition of the animal. These latter points are very important, and statistics stating baldly that sarcocysts were found in such and such an animal without stating how the examination was made, and without a rough estimation of the number present, are of little value in settling such a question as that of the pathogenicity or not of the sarcosporidia. Moulé's work will be again referred to, see page 91.

Roloff (3) found very large numbers of the sarcocysts present in the muscles of sheep which had died in an emaciated condition in Germany. He mentions, further, that although he found them in other sheep they were much more abundant in those dying emaciated. Furstenberg states that in a Rambouillet ram brought into Germany from France, the animal appeared to have died from emaciation, and sarcocysts were very numerous in the body muscles.

Doflein and Prowazek (4), with regard to the subject under discussion, make the following remarks:—

In general, it is very probable that where a large number of sarcosporidial cysts are present paralysis of muscles sets in. Thus Siedam-

grotzky, Laulaine, and Brouwier trace the interstitial inflammation of the muscles in swine to the sarcosporidia. Johne corroborates this. Virchow traces to the parasite the paralysis of the hinder extremities not infrequently present in swine. Brouwier describes the sick animal very well as one which can scarcely walk and has great difficulty in getting up. Strongly infected mice have similarly a difficult waddling gait. Schneidemuhl asserts concerning sheep examined for sarcosporidia that they die with symptoms of a progressive cachexia joined to a dropsical condition.

Fiebiger (5) states that "in the year 1906, in Budapesth, 1·2 per cent of the sheep were excluded from consumption on account of universal sarcosporidial infection." It is probably not straining matters if it is assumed that these animals were not condemned primarily for the presence of sarcosporidia, but that an associated cachexia and emaciation drew the attention of the Inspector to them.

From these extracts, therefore, it may be assumed that advanced sarcosporidiosis has been found by various observers to be associated with emaciation and cachexia. There is no mention, however, of itching and paralysis. This possibly finds its explanation as follows. Apart from the fact that both itching and paralysis may be so slight in cases of veritable scrapie as to be unobservable by even an experienced eye, slaughter-house officials are not the individuals one would select or expect to observe, especially in the riot of a slaughter-house, the symptoms of such a disease as scrapie. In one's own experience there is often quite a considerable difficulty in observing such symptoms, *even with previous knowledge of the disease and of its symptoms*, in a quiet field alone with the sheep. A further explanation of the absence of record of symptoms in such cases is, of course, the fact that the majority of these observations were made on carcases without any opportunity having been given for examination of the animal during life.

So far the symptoms exhibited, especially by sheep, have been dealt with. The disease symptoms produced in other animals will now be considered.

Hutyra and Marek (6) mention the following case: Lameness, first in one leg, then in another, and then in several legs, in a horse, recorded by Lienaux, who found in the excised pieces of muscle sarcosporidia.

Friedberger and Fröhner (6) quote the following cases—viz.: (1) Lameness in a bull; difficulty in rising (and indeed complete muscular paralysis), recorded by Brouwier and Tokerenko); (2) in two pigs loss of appetite, continual lying, arching of back, irregular movements of the hinder parts, pain in the muscles when pressed, hoarseness and fever, trichinosis at first suspected; after slaughtering, the muscles were found to be watery, opaque, and permeated by numerous sarcosporidia. They further state that, according to Hertwig, Miescher's tubes were so numerous in six pigs that the muscular preparations contained as much of tubular as of fibrous matter. The flesh was consequently flabby, extremely watery, and its section surface assumed after a few hours a pale-green colour.

Teichmann (8) gives the following account, for which he states he is indebted to Dr Neubauer, Superintendent of the town slaughter-house at Frankfort-on-Maine:—

> Swine are very heavily infected, and the whole body musculature is attacked. Symptoms of paralysis are especially present in the hinder extremities. In any case, the muscle in massive infection is markedly changed. It becomes gelatinous and watery looking. These changes can be so bad that the flesh cannot be used and must be destroyed.

Neumann (9) quotes the following cases:—

> Virchow has observed in some pigs which were affected, feebleness or *intermittent paralysis of the hind-quarters, ardent thirst, a nodular exanthem, transient symptoms of rouget*, and in one instance lachrymation and a dull appearance of the eyes which might be due to the presence of the parasites in the muscles. [Italics mine.—J. P. M'G.]

He states further:—

> Schulze has met with these parasites (*sarcosporidia*) in the muscles of the fore leg of a horse killed because of being affected with paralysis of the anterior limbs. These muscles were degenerated, and showed calcareous granules twenty mm. long by three mm. broad.

Watson (10) instances the following cases as having come under his own personal observation:—

*Case* 1. Heifer three years old, said to have developed symptoms of "loco"[1] poisoning as a yearling. Received at quarantine station 27th October 1907. Stunted undersized appearance and in poor

[1] A disease of the nervous system caused by eating a poisonous plant.—[J. P. M'G.]

flesh, coat staring and rough. On passing hand over the body, small scurfy nodules could be felt; knots of hair matted with moist branny scales. There were frequent prolonged extensions of the head and neck, accompanied by a more or less constant trembling and agitation of the muscles of these parts, especially of the jaws, and most marked during attempts at feeding, the power of prehension of food being practically lost and mastication very difficult and incomplete. At autopsy there was found gelatinous infiltration of the connective tissues, lungs, and kidneys. Heart and endocardium very extensively infected with sarcosporidia. Skeletal muscle not examined.

*Case* 2. Same symptoms as Case 1, but, in addition, watery discharge from nostrils; dimmed eyes and occasional lachrymation. Kept under observation for three months, during which the disease made steady progress; then, because animal became quite helpless, it was killed. The skeletal muscles were heavily infected with sarcocysts; so, too, was the myocardium. Sarcocysts were also found in the lung, liver, spleen, and kidneys.

*Case* 3. Steer three years old. Similar conditions to preceding cases, but disease not so far advanced. During the past three months, in which the animal has been hand-fed and well cared for, the symptoms have increased in severity. Depression is deepening; muscular action stiff and slow; jaws swollen; sarcocysts found in large numbers in several pieces of excised muscle; present condition of the animal leaves little chance of recovery.

*Cases* 4, 5, and 6. Steer and two heifers, two, three, and two years old respectively. The condition is approximately the same in each—namely, slow sluggish muscular action, depression and a dejected unthrifty appearance. Pieces of muscle were removed by operation,—three pieces from Case 4, three from Case 5, and two from Case 6. In all the muscles examined, with the single exception of a very small fragment of the flexor metacarpi, sarcosporidia were found in large quantities.

He gives (page 4) instances of sarcosporidial infection in two horses suspected of "loco" poisoning, and (page 5) in three horses affected with dourine; and then he gives the following case:—

*Case* 12. In a cachectic filly the cause of the cachexia not known. Filly two years old, one of a batch of six supposedly healthy fillies shipped to quarantine station for experimental work. It was noted on arrival that this animal had an unthrifty appearance, stiffened gait, rough hide, and was in poor flesh. The mucous membranes were pale. She was several times carefully examined for signs of dourine, but none were detected. The cachexia became more evident during the autumn and winter with increasing stiffness of the muscle and gait, especially of the hinder extremities. The animal was found dead in the pasture on 4th March last, the body frozen. The muscles of the œsophagus, tongue, and extensors of the fore arm were infested

with sarcosporidia. Parasites were not seen in the myocardium or the muscles of the eye. No others were examined.

The cases in the cattle mentioned above and the two first horses occurred in "locoed" animals. Watson suggests that the muscular symptoms may be explained by the sarcocyst in the muscles, but states that "it is equally true that the origin of the muscular disturbance may be seated in the nerve cells of the brain as the result of the loco poisoning. If the latter hypothesis is correct, it is a strange coincidence that in the few cases examined the muscles most affected were those in which the parasites were most numerous."

He concludes (page 9) that the parasite sarcocystis, under certain conditions, becomes a very important factor in disease, invading the entire musculature of its host with serious or fatal consequences.

Minchin remarks as follows (11):—

> As a general rule, the sarcosporidia appear to be harmless parasites, which do not make their presence known by any symptoms of disease, and can only be detected by post-mortem examination. Some species are an exception to this rule, and are extremely pathogenic to their host,—for example, *sarcocystis muris* (of the mouse). The extent to which the health of the host is impaired appears to be directly proportional to the numbers of the parasite in the body, and consequently to the power which a given species may possess of multiplying and overrunning the host. In most species the capacity for endogenous multiplication appears to be extremely limited.

Some help in the elucidation of the problem of the pathogenicity of the sarcocyst can be obtained from a consideration of diseases other than sarcosporidiosis, where a parasite invades the primary muscle fibre. Such a condition occurs in trichinosis. Neumann (*op. cit.*, p. 594) states that in the second stage of the disease, which commences from the eighth to the fifteenth day after infection, the appetite gradually returns, but the limbs are stiff and the movements, especially of the hind-quarters, are halting and uncertain, and there is an appearance of paraplegia. Finally, according to Röll, *pruritus* may be developed in various parts of the body.

Friedberger and Fröhner (*op. cit.*, p. 614) mention the case of a one-year-old dog which was fed on very trichinous pork. It subsequently developed tonic and clonic spasms of the neck, and the hind legs were completely paralysed. As regards the

disease in pigs, they remark (p. 614) the following symptoms as occurring in the second and third weeks: "The animals display a peculiar itching, which makes them rub and scratch themselves; also a stiff and constrained attitude of the limbs which may amount to lameness and weakness. They manifest pain, rapidly lose flesh, and constantly lie down." Hutyra and Marek (*op. cit.*, p. 820) express themselves in a like manner. At p. 822 they note that in the disease, as it occurs in man, prurigo is a symptom.

In this chapter there have been gathered together cases from the literature, where a certain set of symptoms during life could find no explanation post-mortem, except in a generalised sarcosporidiosis. This sarcosporidiosis was not found usually by intention, but only accidentally; and if one considers how heavily infected a piece of muscle may be with sarcocystis, without having changed so much in appearance as to draw attention to itself, one is surprised that there are really so many cases on record where symptoms during life have been associated with a sarcosporidiosis of the muscle found post-mortem. It is true that the descriptions of the symptoms during life are not as extensive as one would like; but by piecing together the information, we find that cachexia, paralysis, and itching have all been noted as the symptoms produced during life by an extensive sarcosporidial infection. These, it will be observed, are the cardinal symptoms of scrapie.

Fuller reference might be made here to one symptom of scrapie—namely, itching. It will be seen that in trichinosis, not only do we get paresis of the muscles but also pruritus. The paresis in trichinosis could be explained by the presence of the trichina in the primary muscle fibre. The itching may possibly be a purely reflex thing—a sort of reversal of the usual reflex from skin to muscular contraction. A similar explanation may hold also for sarcosporidiosis, but in it undoubtedly the itching is mainly due to the presence in the sarcocyst of a soluble toxin, which, circulating in the blood, irritates the nerves of the skin and produces the pruritus. The reasons for this view will be given later, when Sarcocystin is being treated of. For the present, however, it should be noted that the main symptom of the disease scrapie is attributable to a soluble toxin produced by the sarcocyst. The paresis

shown by animals heavily infected with sarcosporidia, is in my opinion due, for the most part, to the sarcocyst interfering with the contractility of the muscle fibre; but it is also due, no doubt to some extent, to a myositis caused by the presence of the parasite, as Pluymers (12), Rieck (13), and others have shown.

The present is a fitting place also for emphasis to be laid on my view regarding the causation of scrapie. Scrapie would appear to be due to a *mass* infection with the sarcocystis tenella. Sarcocystis tenella may be present, let us say for the sake of argument, in 100 per cent of sheep; in a large number of sheep this parasite does not increase to any extent, and such sheep show no signs of disease (*vide* statistics below); but in a certain proportion (for causes which we will not inquire into further at present—the fact itself is indubitable) the parasite overruns the host, being present in some cases to the number of 150 sarcocysts in 10 milligrammes of muscle. When this occurs, then, in my opinion, the animal shows evidence of it by exhibiting the symptoms of scrapie, in whole or part.

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# CHAPTER VII.

## ON THE ACTION OF THE SARCOCYSTIN, THE TOXIN PRODUCED BY THE SARCOCYST.

Pfeiffer (1) was the first to show that the sarcocyst possessed a substance toxic to certain animals. He emulsified in sheep aqueous humour, the cysts from the œsophagus of the sheep, and injected this into the trachea of rabbits. Suffocative phenomena, with death in 12-24 hours, followed, together with a hæmorrhagic exudate at the seat of injection. When this emulsion was injected into the thigh muscles death took place with cramps in 24-48 hours. Kasparek (2) killed guinea-pigs and mice by subcutaneous injection of sheep sarcosporidia. Laveran and Mesnil (3) used watery and glycerine extracts of the fresh and dried cysts from the œsophagus of the sheep. One milligramme of the fresh sarcocyst injected subcutaneously into rabbits caused, at the end of 2-3 hours, diarrhœa, œdema at point of inoculation, and lowering of temperature sometimes below 32° C. With a smaller dose less acute symptoms appear, but the animals get rapidly thin and die later. Guinea-pigs, rats, mice, and sheep are much less susceptible, as are also frogs and tortoises. A dog, a hen, and a pigeon lost weight after injection. The sarcocyst contains a toxin, *sarcocystin*, which is very toxic to the rabbit, $\frac{1}{2}$ milligramme killing one kilogramme of rabbit. This toxic power is much diminished by heating. The substance approaches in its action the actions of certain microbial toxins and venins. Rievel and Behrens (4) worked with the sarcosporidial cysts obtained from the musculature of the llama. These cysts were 5-8 mm. long $\times$ 2-5 mm. broad. The experimenters are of opinion that the poison paralyses the central nervous system. Chemically and physiologically they consider it to resemble an enzyme. They suggest that rabbits could probably be immunised against it.

Sabrazes and Muratet (5) used a glycerine extract of the sarcosporidial cysts of the œsophagus of the horse. When this is injected subcutaneously into the rabbit, it gets thinner, weaker, cold, and in from 5-6 hours after injection a profuse fœtid diarrhœa sets in. The fatal dose for a rabbit of 2 kilos. was 100 cysts 8-10 millimetres in length. Mason (6), using emulsions of the sarcocyst of the buffalo in normal saline, produced by subcutaneous injection into rats, depression, a staring coat, diarrhœa, and death in two to three days. Teichmann (7) found that the sarcocysts from the œsophagus of the sheep contained a very active poison for the rabbit, with a minimum lethal dose for this animal of ·0002 grm. of the dried substance. The poison, according to him, located itself in the central nervous system, being bound to the lipoids existing there. It could be recovered from the brain by treatment with ether and other reagents. When suspended in water it loses its activity by heating at 100° C. Toxicity can further be removed by mixing it with lecithin, with sheep serum, and especially with the serum of an immunised rabbit. The injection of this immune serum subsequent to toxin injection as a cure is useless. Previous treatment of an animal with the immune serum does not confer immunity. There is no hæmolysis of the red blood corpuscles of sheep or rabbit. Rabbits are very susceptible to the poison; canaries also; mice slightly; while rats and guinea-pigs are refractory. The symptoms in rabbits are paresis of the hind legs and somnolence: they sit in one place with their eyes shut and eat nothing. They die with convulsions. Teichmann and Braun (8) state that the sarcosporidial cysts contain a true toxin which is thermolabile, filtrable, and soluble in salt solution. It is toxic only for rabbits. Rabbits can be immunised against it. Passive immunity can be conferred by mixing toxin and antitoxin *in vitro* before injection, or by simultaneous injection of these two substances. It agglutinates the blood corpuscles of sheep, guinea-pig, man, horse, pigeon, but not the rabbit. This agglutinin is not identical with the toxin. Immune serum has complement-deviating properties against sarcosporidial extract. Huntemüller (9) thinks that the toxin above described is really a bacterial toxin, because in the large sarcosporidial cysts a great number of different kinds of bacteria are present.

Teichmann and Braun (10) defend their position in a circuitous way, but it is left for Knebel (11) to demonstrate that extracts of sarcosporidial cysts, experimentally shown to be absolutely sterile, can produce on injection the symptoms usually attributed to the sarcocystin. Cominotti (12) found that the animals most susceptible to the action of the toxin were rabbits and sparrows. The minimal lethal dose for rabbits was ·0001 gramme of the dried cyst. The clinical picture after the injection of the poison was one of paralysis. Anaphylaxis to a second injection can be produced in the guinea-pig. Rabbits can be actively immunised. An immune serum very fugitive in its results can be produced in goats by the injection of the toxin.

The extract of sarcosporidial cysts has thus been shown by the authors above quoted to be toxic for several animals, but especially for the rabbit. The symptoms produced in the rabbit are diarrhœa, lowering of blood pressure, and fall of temperature. A paralysis of the muscles and cramps are mentioned by some as existing. There is no mention, however, as will be seen, of a *stage of excitation* previous to the stage of depression, and *no mention of pruritus*. The significance of these two last symptoms will be referred to later in relation to my own work on the subject.

In connection with this investigation, several observations have been made by me on the effect of injections into rabbits of extracts of muscles from scrapie sheep. These extracts were found to contain a toxic substance similar to that described above, and derived from the sarcosporidia present in the muscle. This toxic substance was obtained by mincing the scrapie muscle, allowing the minced meat to stand at room temperature for twelve hours, and then pressing the juice out with a meat press. The toxic action of the fluid thus obtained was found experimentally to depend on the number of sarcocysts present in the muscle. *Corresponding extracts from the muscle of normal sheep (without sarcocysts) had no toxic effect*. The action of the toxin was chiefly tested on rabbits, as guinea-pigs were found insusceptible to it, at least when doses comparable to those used for the rabbits were employed.

The following is a protocol of one of these experiments. The extract in this case was made from a case of scrapie

whose muscles were very heavily infected with sarcocysts (100-150 per 10-15 milligrammes). The experiment was made on May 7, on a pregnant white doe whose weight previous to injection, at 11.45 A.M., was 3540 grammes, and whose rectal temperature was 100·8° F. Four c.c. of the above fluid was injected intravenously into the ear vein at 11.55 A.M.

12.15. Coat staring; sitting very quiet; *irritable flicking* of ears; fibrillary tremor down the back; walks about; uneasy; *shaking its head; licking first hind paws then fore paws;* very restless; shaking itself all over; biting its paws feverishly; throwing out its fore feet and hitting the ground with them.

12.20. Still continuing as before; constantly shaking its head; very restless; running about actively; biting paws feverishly; throws out first one fore foot then the other, then bites at them feverishly; shakes its ears; jumps in the air and bites at its belly.

12.25. Champing of the jaws begins; begins to scratch the back of its ear; reaches forward its head as if to bite one foot, and then suddenly in a frenzy seizes another one; head shaking, &c., as before.

12.30. So intent on biting its feet, &c., that it pays no heed to any one approaching; urine passed; head shaking, feet throwing, and biting as before.

12.35. As before; seems not to know what to do with itself.

12.42. Lying down on belly with hind feet stretched out behind it and fore feet in front. It suddenly gets up from this position, shaking its ears and champing its jaws; fine tremor all over it.

12.45. Very restless; lies down on its abdomen, with its eyes shut and its ears laid back.

12.47. Again shifting about restlessly. Temp. 102·8° F. Formed fæces passed.

12.50. Shaking ears, champing jaws, &c.; fine tremor on nostrils; sneezing.

12.53. Quieter now.

12.54. Lies down extended, with eyes shut and ears laid back.

12.57. Gets up again, champing jaws still going on.

1.25. Sitting up, constantly shaking ears and champing jaws; its eyes are shut.

1.35. Very restless; biting its fore paw; shaking head and ears very vigorously; champing jaws.

1.47. No change.

2. No change; no sign of general weakness.

2.10. Temp. 102·8° F.; no diarrhœa; no change; fine tremor on nose.

2.45. No change.

3.35. Lying on floor with fore feet stuck out in front, ears laid out along back, which is hollowed; nose stuck up in the air; eyes shut. Temp. 103·6° F. No limpness; point of nose trembling; no shaking of head or ears; occasional champing of the jaws. There is

no tonic spasm in this attitude, for when disturbed it immediately assumes a more natural attitude; ears are not cold, and they bleed easily. Rabbit moves about the cage all right.

4.5. Sitting in same attitude as at last observation.

5. Do. No muscle weakness; formed fæces passed.

6.30. Very dull; eyes shut; no restlessness now; breathing very laboured; no diarrhœa; eating its fæces; offered water—will not drink it; when disturbed, moves inquisitively about the cage. Temp. 102·8° F.

9.20. No diarrhœa. Temp. 103° F. No restlessness; breathing laboured; no paralysis.

*May* 8, 9.30 A.M. Very limp; sitting on the floor with its nose resting on the ground and eyes shut; breathing difficult; no restlessness; very dull; nose very blue. Temp. 97·2°. Can walk about of its own accord; no diarrhœa.

Died at 12 o'clock. Post-mortem: lungs healthy; heart very dilated; abdomen no peritonitis; small intestines dotted all over with petechiæ, contain gelatinous watery mucus; contents of cæcum fluid; urine normal. Cultures made from the heart blood remained sterile.

Sixteen other rabbits were injected intravenously with varying quantities of muscle extract from scrapie sheep. A considerable number of these experiments were done with the same muscle extract as was used in the above experiment, but several of the experiments were done with extracts made from other cases of scrapie. The symptoms exhibited by these rabbits may be shortly summarised as follows:—

Following on the injection, and lasting for different periods in different animals, is a *period of excitation.* This is evidenced by restlessness—moving about from place to place; champing of jaws; shaking of ears; biting the feet, pieces of paper, fæces, or the walls of the cage; increased pulse and respiration rate, and rise of temperature. This excitation stage was present in all of these sixteen animals, but in none of them to such a marked degree as in the case described in full above.[1] This stage, after lasting for from one to three or four hours, gave place to a stage of marked depression, evidenced by fall in temperature (sometimes to 92° F.); diarrhœa; slowing and weakening of the respiration and heart; lowering of the blood pressure, as evidenced by the blueness and coldness of the ears

[1] In this connection, the inconstancy of the itchiness in sheep affected with the disease should be noted.

and muzzle; great weakness of movement, and absence of desire to move about, due to the general weakness and *not due to an actual paralysis.* In this stage, too, there were observed fine muscular tremors all over the body. The animal became haggard, with staring coat, and lost weight rapidly. During this second stage, in some of these cases there was occasionally an absence of diarrhœa, though in all of them, as happened in the first case described above, the intestines were found, post-mortem, to be filled with liquid contents.

The post-mortem examination of these animals showed the flesh to be *very dry,* due in all probability to the loss of liquid by the intestines; there was no sign of hæmorrhages or congestion in any part of the body; the stomach was full of food even in cases where the animal had survived two days; the small intestines were filled with clear gelatinous liquid, while the contents of the cæcum were fluid; no growth of organisms was obtained from the heart blood, and the blood itself was not hæmolysed.

These experiments were controlled by the injection into rabbits of an emulsion, made in exactly the same way, of mutton containing practically no sarcocysts. Three rabbits were injected intravenously, one with 10 c.c. of the extract, and two with 5 c.c. These animals exhibited no symptoms, and remained alive. The experiment was further controlled by the injection intravenously of sarcocystin prepared in the following way. The sarcocysts in the œsophagus of the sheep were shelled out and dried in a vacuum over sulphuric acid. Ten rabbits were injected intravenously with 10 milligrammes of this dried powder emulsified in saline. They exhibited all the symptoms described above, and died in a short time.

Several rabbits were injected subcutaneously and intraperitoneally with the scrapie muscle extract. These animals, without exception, died; but though they exhibited the depression symptoms to a marked degree, the excitation stage was not so obvious. There was no inflammatory reaction or œdema at the seat of inoculation, nor was any growth obtained from the heart blood.

The following experiment was performed to see if the toxin was circulating in appreciable quantities in the blood of a scrapie sheep. The sheep was bled to death, and its serum

obtained: this serum was heated at 56° C. for half an hour (to destroy the toxic principle for rabbits which exists in even normal sheep's serum). This may have had a weakening effect on any sarcocystin present, for heat has some injurious influence. However that may be, 20 c.c.'s of the serum thus treated were injected intravenously into a rabbit weighing 1300 grammes. This produced no effect. It was conceivable, however, that this dose might do one of two things—either render the animal passively immune or passively anaphylactic. Next day, therefore, it was injected intravenously with 2 c.c. scrapie muscle extract, and died with exactly similar symptoms to a control animal. This rabbit, therefore, was not rendered passively immune or anaphylactic by treating it the day previously with scrapie sheep serum. The effect of giving a rabbit the scrapie sheep serum half an hour before giving it the scrapie muscle extract was next tried. The rabbit weighed 1160 grammes and received 20 c.c. scrapie sheep serum at 10.30 and 1 c.c. scrapie muscle juice. As before, no immunity or anaphylaxis was observed.

The next experiment was done to see if the mixing of the scrapie sheep serum and the scrapie muscle juice *in vitro*, and incubating for one hour at 27° C., would have any effect on the toxicity of the sarcocystin. Parallel experiments were put up with scrapie sheep serum and normal sheep serum, and it was found that while the control animal died in twenty-four hours, the rabbit treated with the scrapie sheep serum mixture lived for three days, diarrhœa appearing only on the third day.

It was further found that scrapie sheep serum, acting in conjunction with scrapie muscle extract, possessed the power of deviating complement in a hæmolytic series.

The extract of scrapie muscle did not possess hæmolytic properties towards sheep, rabbit, or guinea-pig corpuscles *in vitro*. It preserved its toxic action for a long time if kept in the cold room under toluol.

The heat resistant power of the toxin in the muscle extract was not determined because of the coagulation of the associated muscle proteid; further, because of the associated muscle proteid, the production of antibodies to the toxin could not be determined in the rabbit.

The toxin appears to be, at least in greater part, present in

the cellular and particulate elements of the cyst, for repeated washing with large amounts of saline did not reduce the toxicity of the contents of the cyst.

Strong suspensions of the dried cyst and of the fresh cyst, when applied to the conjunctiva of the rabbit, produced no local or general effect. Large doses given to rabbits by the stomach-tube did not produce diarrhœa or any general symptoms. It has been stated (Rievel; Behrens; Teichmann) that sarcocystin s a poison for the central nervous system, and an attempt was made in the following way to test this view. Two rabbits of equal weight and from the same litter were injected with ½ c.c. of a strong emulsion made from fresh sarcosporidial cysts from the œsophagus of a sheep. One was injected intraperitoneally, the other intraspinally. The rabbit injected intraperitoneally was dead several hours before the intraspinally-injected one. Both showed the well-known symptoms after injection. Paralytic symptoms, or anything indicating a special action on the central nervous system, were absent even from the intraspinally-injected case. Such an experiment would seem to show that the central nervous system was not primarily or specially affected by the toxin.

If the toxin then does not act on the central nervous system, on what part of the body does it act? When pruritus is produced, the assumption is that the nerve endings in the skin are being affected. It may be surmised, therefore, with some degree of probability that sarcocystin acts on the nerve endings in the skin. It would appear that it can only do this from the blood stream, for application to the skin or conjunctiva does not produce symptoms, at least in rabbits. The other prominent symptom produced—namely, diarrhœa—may also be a surface one and due in all likelihood to the irritation by the toxin of the nerve endings in the intestinal mucosa. In this connection Cushny ('Text-book of Pharmacology,' p. 96) has the following statement relative to the mode of action of purgatives: "The action of the purgatives is generally considered to be purely local and strictly analogous to that of the skin irritants. The irritation of the epithelium and of the nerve ends leads reflexly to increased activity of the deeper layers which manifests itself in the bowel by contraction of the muscle, in the skin by hyperæmia;" and

similarly Dixon ('A Manual of Pharmacology,' p. 250) speaks as follows: "The increased peristalsis is caused by direct irritation of the intestines. The epithelial cells appear to take up a minute amount of the irritant drug which acts as a powerful stimulus to the peripheral sensory endings in these cells. A local reflex occurs through the nerve cells in Auerbach's plexus, leading to augmented peristalsis." Here, again, there is absence of purgative effect when the poison is applied to the surface of the intestine by stomach-tube or injection into the intestine. This could be explained by a question of dose or effective solubility.

With less justice, but still with a certain amount of evidence to support it, it may be supposed that the blood-pressure changes are due to an action on the nerve endings of the blood-vessels.

Professor Ritchie drew my attention to the similarity in the symptoms produced by the injection of this toxin and those of subacute anaphylaxis (diarrhœa, lowering of blood pressure, and itching). It would appear that the similarity between these two conditions extended even further to an actual identity in the method of production of the symptoms. In anaphylaxis, indeed, one of the methods of death is said to be by an action on the non-striped muscle of the bronchi causing asphyxia by a spasmodic contraction (Auer and Lewis, 'Journ. Expt. Med., xii., 1910). I have not looked carefully for, and so have not had the opportunity of observing whether an action on the bronchi by sarcocystin takes place, but preliminary experiments would seem to show that atropine has some effect in modifying the action of sarcocystin on the rabbit with relation first to the diarrhœa and second to the fatal effect.

The pharmacological action of sarcocystin corresponds with that of such substances as the extract of the tentacles of sea anemones (Richet, 13); of mussels, &c.; and of the fluid from the hydatid cysts of man, ox, sheep, &c. (Perret, 14). These latter, like sarcocystin, are animal products, and, like it, produce the pharmacological effects just described. Special attention may be directed also to one important similarity. Both produce a stage of excitation *with itching*, and Richet (*op. cit.*) emphasises the fleeting nature of this itching stage, and the necessity of looking very closely for it, otherwise it may be missed altogether.

In the literature very varying accounts are given of the susceptibility of various species of animals to sarcocystin. For one investigator one species of animal is susceptible and another not; and for another investigator the reverse is the case. This may be a question of dose or personal equation of the animal or species. The only animal which has been much employed, and which seems to be universally susceptible, is the rabbit. But even with it there is some want of uniformity in the train of symptoms following an injection. This depends sometimes on the mode of injection. Thus, animals injected subcutaneously do not show so marked an excitation stage as those injected intravenously. Again, diarrhœa was markedly present in some cases and nearly absent in others.

It may be noted in passing that the rabbit which showed the pruritus most markedly amongst those experimented on above was in the final stages of pregnancy.

In concluding this chapter, one would emphasise the fact that the most prominent symptom in scrapie—namely, itching—has been reproduced by me in rabbits by an injection of sarcocystin and the extract of scrapie sheep muscle.

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# CHAPTER VIII.

## ON THE MODE OF SPREAD OF SARCOSPORIDIOSIS FROM ANIMAL TO ANIMAL IN CARNIVOROUS ANIMALS.

The method of spread of the sarcocyst from animal to animal is as yet but imperfectly understood, and indeed no information of any value on this subject was forthcoming till Theobald Smith performed his experiments on mice in 1901 (1). Previous to this, however, several observations on the subject had been made, but they had led to no definite result. These had mostly been performed by individuals who had in their mind a possible analogy of this disease with Trichinosis, and consequently the experiments consisted in feeding various animals with sarcosporidial flesh. Amongst those who performed such experiments were Virchow and Manz, who fed such animals as cats, rabbits, guinea-pigs, rats, and mice, with sarcosporidial flesh without however infecting them. Cobbold himself ate at two meals a sheep's heart raw which was intensely infected with sarcocysts, and Moulé stated in 1887 that ten years previously he had eaten a piece of raw sarcosporidial flesh as an experiment, and that at the time of writing he could find no trace of sarcosporidiosis in himself. Kasparek (2) (1895) injected a mouse subcutaneously with the contents of a sarcosporidial cyst from the œsophagus of a sheep. It died in twenty-four hours, and on examination of the heart blood he states that he found sickle-shaped bodies. In a similar way he injected a guinea-pig subcutaneously, and found sickles in the blood four hours after, but not twelve hours after injection. Pfeiffer (3) had performed in 1892 a somewhat similar experiment with a somewhat similar result, and suggested the possibility of a blood-sucking intermediate host. These experiments are not, however, convincing, and are merely mentioned in passing. Such facts as these are only of historical interest, for, as mentioned above, the first

experiments which really threw some light on the subject were performed by Theobald Smith in 1901 (*loc. cit.*). Smith succeeded in infecting grey mice by causing them to eat the bodies of some of their fellows which had died of sarcosporidiosis. He judged that he had thus artificially infected the mice by the fact that the percentage of infected mice among those fed was much larger than among the "stock" mice.

The earliest stages of the parasite were detected by him *forty to fifty days* after the last feeding with the infected flesh. He notes this long period between the act of infection and the growth of the parasite in the muscles, and interprets it in one of two ways—viz., either (1) the parasite requires a long time to store up enough energy to undergo the rapid growth and multiple division of the nucleus terminating in the formation of spores and sporozoites; or (2) the sporozoites after ingestion develop into sexually mature organisms in some part of the body in a manner analogous to the genus coccidium. After fertilisation the female organism migrates into the muscle fibres and there passes through the process of sporogony.

Stages of development in the intestine were looked for by him but none found. He ventures the opinion that it may later be found that the parasite reaches the muscle fibre soon after ingestion, where it remains undetected until the multiple division of the nucleus begins, and the organism by its rapid growth and increased affinity for chromatin dyes becomes recognisable. A parasite reproduced in a figure in the text of his article was found fifty-one days after feeding, and measured only ·05 mm. by ·016 mm.

He states that in about seventy days after feeding, the parasites enter the stage of spore and sporozoite formation. *The cyst therefore ripens in two and a half to three months after the date of feeding.* He thinks that the method of infection is direct, and that there is no intermediate host such as biting insects, &c. When the parasites are very large and numerous he thinks that disturbances in the movements of the animals should occur, and as a matter of fact such mice are frequently found slow in movement and ill. He gives one case to show that a second infection on the top of an already existing infection of a mouse with the sarcocyst by feeding is unlikely, in his opinion. In 1905 (4), in another paper, he states again that

there is no evidence of the disease being carried by ectozoa; and the fact that the disease had been kept going in the laboratory for class purposes by feeding healthy animals on the infected flesh of their dead fellows demonstrates the efficiency of this as a method of carrying on the disease. He gives a single observation which he states goes to show that these parasites *may* not be transmitted from parents to young. In the autumn of 1901, only two adult grey mice were left from a lot infected during the year. A litter of three young were born about that time, and these were allowed to live until January 19, 1902, when they were three-quarters grown. *All* were chloroformed. The pair of adults were heavily infected, but no parasites could be detected in any of the young. This is possibly the first reference in the literature to the question of the disease being passed on by congenital infection. It will be seen that Smith guards himself by saying that the parasites *may* not be transmitted. Apart from this altogether, although the pair of adults were heavily infected at the time when all were killed, there is nothing to show what their condition was when the young ones were born; and, again, there is no record of the *exact* age of the young mice when they were killed. It is quite possible that they were too young for the parasites to be evident, more especially if, as might quite well be the case, they received a very light infection from their mother, who can quite well be supposed to have been in an early stage of the disease at the time of their birth.

Koch (5), in 1904, infected mice with sarcosporidiosis by feeding them on flesh from other sarcosporidially infected mice; and L. Nègre (6), in 1907, further confirmed Theobald Smith's observations. He also found (1) that young mice were much more easily infected than old ones. (2) That parasites only appear in the muscles forty-five days after the ingestion of spores, and their appearance may be much later. (3) The evolution of the sarcocyst takes place in eighty to ninety days, counting from the date of ingestion: it is at the end of this evolution that the spores have their maximum infecting power. (4) In the same mouse and in the same muscle parasites are found in various stages of development; at the end of infection the parasites of the abdominal muscles are more developed than those of the other muscles. When the infection is benign, it is

in the abdominal muscles that the parasites are most numerous. (5) That in a lot of mice raised in the same box, and infected at the same time and in the same conditions, the parasite does not always evolve with the same rapidity. One can find in a mouse killed sixty days after the ingestion of spores, younger stages than in a mouse killed fifty days after. (6) The proportion of mice infected by ingestion of sarcosporidial muscle is greater when the mice are together in the same box than when they are separated. (7) Attempts to infect mice by inoculation of spores under the skin, or into the peritoneum, have always failed. (8) Spores preserved in ordinary water for more than three or four days lose their infecting power.

He states that there must be an intestinal stage of the parasite, for the fæces of mice which have eaten sarcosporidial flesh are capable of infecting healthy mice from the fifteenth to the fiftieth or sixtieth day after the infection. These fæces remain infective if kept dry for a month, and if heated for fifteen minutes at 65° C., but lose it if they are heated at 85-90° C. for a similar period. As before, the parasite appears in the muscle forty-five days after the ingestion of the fæces, and there is the same proportion infected by feeding on fæces as by feeding on spores. He could not, however, find an intestinal stage of the parasite; but in 1910 (7) he found a protozoan cyst in the duodenum of a mouse, which was killed twenty-two days after a feed on sarcocyst flesh. He thinks that this cyst, as likewise the cysts found by Gilruth (8) (*Gastrocystis gilruthi*) and Chatton (9) in the stomach of a sheep, may correspond to the intestinal stage of a sarcosporidian. There is, however, no evidence for this supposition either in one case or the other. Negri (10), in 1908, fed white rats on the mouse sarcosporidium and produced the disease in them. He further produced this disease in guinea-pigs by a similar method of feeding. He finds, however, the sarcocyst much changed anatomically by its change of host. Darling (11), 1910, similarly produced the disease in guinea-pigs by feeding them on *sarcocystis muris* flesh. He did not find the sarcocyst in the muscles of the guinea-pig till from 152-164 days after feeding. Negri (*loc. cit.*) had found it fifty days after the first feeding. Erdmann (12), 1910, produced infection in mice by feeding them on the sarcocyst of the sheep. V. Betegh and P. Dorcich

(13), in 1912, fed two ducks and a fowl on cysts from the œsophagus of the sheep, and produced in all a universal sarcosporidiosis which was most marked in the ducks, and in them in the stomach wall. It may be mentioned here that sarcosporidia have been found naturally existing in birds by Stiles and others.

From what has been said, it will be seen that in various animal species, the sarcocyst has been passed from one member to another by feeding on infected flesh. The sarcocyst of one species of animal has even been transferred to another species by feeding the latter on the infected flesh of the former. When this takes place, a change in the morphology of the parasite occurs, as Darling (*loc. cit.*) and Erdmann (*loc. cit.*) have more specially mentioned. Other facts that one derives from a consideration of the literature mentioned above are, that the fæces of an animal fed on sarcosporidial flesh remain for a long time infective, as mentioned by Nègre; that a considerable time —45 days according to Smith and Nègre, and 152-164 days according to Darling—elapses between the time of infection and the appearance of the parasites in the muscle of the infected animal, and that for the full development of the sarcocyst in the muscle, a period of two and a half to three months must elapse (Smith). While, therefore, we have some idea of how the disease may be passed on in carnivorous and omnivorous animals, we have as yet no information as to how it may be passed on in graminivorous animals such as the sheep, which question, however, will be discussed in the next chapter.

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# CHAPTER IX.

## METHOD OF SPREAD OF SARCOSPORIDIOSIS IN GRAMINIVOROUS ANIMALS.

As we have seen in the last chapter, a period varying from one and a half to five months may elapse between the feeding of a carnivorous animal with sarcosporidial flesh and the recognition of the parasite in the muscles of the animal so fed. If, therefore, sarcocysts are found in the muscles of young animals of the ages one and a half to five months, especially of animals of the younger age, then one might be justified in suspecting that the infection took place before birth. Roloff (1), 1867, stated that he had found the sarcocyst present in young lambs and swine of a few weeks old, and even in lambs immediately after birth, and in these last they were usually most numerous in the internal and external perimysium of the œsophagus. Bertram (2) stated that in the *embryos* of sheep, swine, and cattle, he could not find sarcosporidia. Ferret (3), 1903, observed inside a muscle fibre in a two-months'-old lamb, a mulberry-like heaping of cells, with thirty elements, but devoid of a capsule. Bergmann (4), 1913, found the sarcocyst present in 6 per cent of calves aged from six to eight weeks, and in 8 per cent of lambs of from six to ten weeks old. He further obtained sarcosporidial cysts in a six-weeks'-old calf and in a six-weeks'-old lamb. According to Bergmann, one finds them earliest and best at the lower end of the œsophagus next the stomach, and next most frequently in the rest of the œsophagus.

During the spring of 1913 I examined a large number of sheep *embryos* from mothers heavily infected with sarcosporidia, and failed to find any parasites in them, thus confirming Bertram's observations. At that time, too, I examined lambs

of various ages derived from such mothers, and the earliest age at which I found the parasite was at three months. This was in a half-bred lamb, and the sarcocysts were fully developed and very numerous. Smith mentions that the cyst in experimentally-infected mice took two and a half to three months to ripen. If conditions are similar in the sheep, this would place the date of infection in this case at or before birth.

At that time I had not seen Bergmann's paper, and did not appreciate the importance of examining the lower end of the œsophagus. So now, in the spring of 1914, I have repeated my observations on this point, giving particular attention to the region just mentioned. The lower end of the œsophagus was examined by serial sections in lambs (born from scrapie mothers) of the following ages: two 2 days old, one 16 days, one 18 days, one 22 days, one 27 days, and two 29 days. Nothing of the nature of a sarcocyst was observed in any of the sections.

When mice are infected artificially by feeding, the dose of infected material given them is *large*. If, therefore, lambs at and below one month and a half found to contain sarcosporidia are infected by feeding, such infection must have taken place by their swallowing, in the milk or otherwise, some heavily contaminated excretion from the mother. This presupposes that the sarcocyst can gain access to such excretion—*i.e.*, to an excreting surface of the body of the mother. It is possible that it may do so in some small or ordinarily invisible or unrecognisable form; but so far as the sarcocyst is concerned there appears to be no evidence microscopically of its being in a position to get access to such a surface; and in this connection the skin, the alimentary canal, the genito-urinary passages (male and female), the respiratory tract, and the lactating and non-lactating udder from heavily-infected sheep, have been examined by me. Nowhere was such a condition of matters found that one could suppose it possible that the parasite could break through on to any surface communicating with the exterior.

In passing, it should be noted, further, that if we suppose for the moment that the disease arises in the lambs from feeding, as in mice,—if we consider the relatively larger size of the lambs as compared with the mice,—it would appear probable at

least that the lambs must have been very early and heavily treated with infected material to bear out the hypothesis that the disease is passed on by alimentation.

It has been suggested that sarcosporidiosis is passed on by biting insects. Pfeiffer and Kasparek, as mentioned above, suggested the passing on of the parasite by means of an intermediate host. Probst and Francis, in 1910, quoted by Prowazek (5), are stated to have found sarcocyst sickles in the heart blood of certain animals. Until further evidence is forthcoming, one must suppose it likely, however, that these came from sarcosporidial cysts in the muscle of the heart. Minchin (6) attributes to Watson the statement that spores are to be found in the circulating blood, and draws attention to the possibility of this indicating the transmission by an intermediate host. Watson's original paper ('Journ. Compar. Path. and Therap.,' vol. xxii. pp. 819) is, however, very indefinite on the subject, and may or may not bear this interpretation. I personally have examined numerous films made from the ear-veins of a large number of different sheep heavily infected with sarcosporidia, and also of separate infected sheep at intervals of three days for several months, and in no case have I ever seen anything resembling a sickle or a possible derivative therefrom.

To examine the question more closely, ticks are not essential for the passing on of the disease, for it is kept going among sheep that have no ticks on them. Nor are keds (*Melophagus ovinus*) necessary, for keds would appear not to be able to live on the short-haired lambs during the first few weeks of life, and the result of an experiment which I have performed during last year, whilst showing other things as well, proves that the disease can be kept going without them. During April and May of 1913, four lambs from four scrapie sheep were obtained *as soon as they were born*, and before the mothers had even licked them. They were removed at first to a byre where no sheep had ever been before, and later to a field where a similar condition prevailed. No sheep were ever allowed near them. They were looked after by an attendant whose duties did not bring him in contact with other sheep. They were brought up on cow's milk until they were old enough to live entirely on grass. When they were about one month old, living keds from scrapie sheep were applied to two

of them, and these two kept apart from the others. No further step was taken until January 1914, in order that if sarcocyst did develop, there would be no doubt of their actual presence. Then pieces of muscle were examined from the gluteal region of all four, *and in all four fully-developed sarcosporidial cysts were found in as large numbers as in lambs from scrapie mothers and of the same age brought up under natural conditions.* In the lambs to which keds had been applied the keds were in very large numbers at the time of this examination, while neither keds nor insects of any kind could be found on the other two. Hence it would appear that keds are not essential for the propagation of the parasite from animal to animal; and from the experiment just described it would appear that no conclusion could be drawn from it other than that the parasite is passed on by congenital infection of the lamb from the mother.[1] The possible method by which this is done has been discussed in Chapter V.; but before concluding this chapter, some circumstantial evidence will be considered which points to the same conclusion and which one can derive from the epizootiological facts of the disease.

1. The disease scrapie in sheep is associated with a *very gross* development in the muscles of the sarcocystis tenella when the sheep is about two years old.
2. It is a well-known epizootiological fact in connection with the disease that a scrapie mother almost without exception gives rise to a lamb which later develops scrapie.
3. Scrapie symptoms also appear at a definite time after birth,—two years after. If the disease were a simple infection, a definite time relation of the majority of the cases to the time of birth would appear to be unnecessary—*i.e.*, cases should crop up irregularly at all age periods.
4. No other causation than that of the ewe infecting the lamb in the uterus could explain the following facts:—
   (*a*) Scrapie mothers giving rise to scrapie lambs almost without exception. This happens

[1] May 1914. One of these lambs appears to be already rubbing itself. Its tail is at present bared of wool.

even when the lamb is suckled on a healthy foster mother.

(*b*) Lambs from healthy sheep suckled on scrapie mothers do not become infected. (French experiments referred to in the Preface.)

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# CHAPTER X.

## OBSERVATIONS AS TO THE PRESENCE OF SARCOCYSTS IN THE MUSCLES OF APPARENTLY HEALTHY SHEEP.

In this chapter it is proposed to give some observations made by me on the presence of sarcocysts in the muscles of sheep to all appearance healthy, which were slaughtered for human consumption in the Edinburgh slaughter-house. Incidentally it may be mentioned that the samples examined were obtained from a butcher who has the reputation of buying the best sheep that are killed in the Edinburgh slaughter-house. The statistics given, it may be stated, take no cognisance of the presence or absence of sarcosporidial tumours (*Balbiana gigantea*)[1] in the œsophagus. They refer to the presence or absence microscopically observed of the parasite in the skeletal muscles. Statistics already existing on this subject are those of Moulé referred to above (p. 62 *supra*). Moulé's figures show that he was dealing with heavy sarcosporidial infections —as heavy in many cases as I have seen in my scrapie cases. The observations were made on sheep seized for emaciation in the slaughter-house and not examined by Moulé during life, nor is it possible to say from what district the sheep came. Taking into consideration the statement made by Besnoit and Morel (*vide supra*, p. 25) regarding the prevalence of *La Tremblante* in certain parts of France, the possibility of the sheep having suffered from scrapie cannot be excluded. Bertram (1) has some statistics relative to the question, but it is impossible to say to what variety of the parasite—œsophageal, or small and in the muscles—he refers. Further, he gives no idea of the

[1] *Balbiana gigantea* are large sarcosporidial tumours easily visible to the naked eye, found in the œsophagus of the sheep and some other animals. Most authors, including Bergmann (*vide infra*), believe them (in the case of the sheep) to be the same as the intrafibrillar sarcocystis tenella. It is interesting in this connection to note that in my scrapie sheep which were heavily infected with sarcocystis tenella in no case did I find *Balbiana gigantea*.

numbers present, and does not state whether the animals showed symptoms during life. He remarks as follows: "From the month of May to December, among 185 sheep examined I encountered 182 affected with sarcosporidia." Such a statement is, however, valueless, and should cease to be quoted in the literature.

Bergmann (2), 1913, examined in Sweden, 139 sheep, all over one year old. The method employed was to examine 0·5 gramme muscle by compression preparations—two from the upper end of the œsophagus and two from the lower end. The rest of the œsophagus, the draphragm, and the abdominal muscles were examined microscopically. He found intrafibrillar sarcocysts in 76 per cent of these sheep. He also examined 342 lambs of about three months old, and found the sarcocyst present in 20 per cent of them, chiefly in the œsophagus.

The examination by me for the presence of the sarcocyst was conducted in the following way. Usually specimens from twenty sheep were examined on each occasion. From each sheep two pieces of muscle were taken—a part from the diaphragm and a part from the sternomastoid. The reason for selecting these muscles was that by sampling thus the carcase was not injured. The specimens were taken at the slaughter-house under the supervision of a veterinary surgeon. The two specimens from each sheep were put together in small corked bottles and the number for the day sent to me at the laboratory for examination.

The method of examining was as follows. A piece of muscle, of a size,—found at first by actual weighing,—equivalent to 10-15 milligrammes, was torn off with a pair of toothed forceps. This was put on a slide and teased up with needles in 10 per cent glacial acetic acid coloured deeply with Thionin blue. The stain was allowed to act for five minutes, at the end of which time the parasites were stained a deep blue. A second slide was then put on the top of the preparation and the two slides squeezed together and clamped. An examination was then made under the low power of the microscope, and the parasites, which were easily recognisable (see fig. 25), counted in the *whole* preparation. *By this method the number of parasites present in a* 10-15 *milligramme piece of the muscle* was found. No second examination of a piece of

Fig. 25.—From teased preparation of scrapie sheep muscle in 10 per cent acetic acid, coloured with Thionin blue, showing sarcosporidia × 80.

muscle was made; so that the statistics given below deal with only one 10-15 milligramme piece of muscle, and that the first piece taken *at random* with the forceps.

The observations referred to first deal with hoggs (one-year-old sheep), and extend from January to April 29, 1913. These animals, from a butcher's point of view, were in the pink of condition. The statistics regarding them are given in Table I. (pp. 94, 95.)

The first point to note in connection with the table is that the great majority, if not all, of the sheep examined came either from the scrapie area itself or from a district almost certainly supplied with stock for fattening purposes from that area. The fact that two sets of observations (March 31 and April 8) deal with stock from Fife is not an exception, for Fife is supplied to a great extent with lambs for fattening purposes from the scrapie area. The further fact that these lambs are nearly the worst affected with sarcocysts—100 per cent and 94·7 per cent infection—supports this to some extent, for the lambs would probably be from such a bad stock as to be unsaleable nearer home.

The next point to notice is that the observations deal mostly with half-bred and Oxford Down half-bred crosses. Two observations have been made on Cheviot hoggs, and in both cases the sarcocyst was present in a large per cent of the sheep,—in one case 100 per cent, in the other 95 per cent. The parasite appears to be present as often in the half-bred as in the Down crosses; and as regards heaviness of infection the one variety seems to have as many of its members heavily infected as the other.

[Table I.

TABLE

| Date. | District from which Sheep came. | Breed. | Number of Sheep examined. | Sarcocyst not found in. | Sarcocyst found in both neck and diaphragm. | Percentage. | Sarcocyst found in neck alone. | Sarcocyst found in diaphragm alone. |
|---|---|---|---|---|---|---|---|---|
| Jan. | | | | | | | | |
| 21 | S.-E. Scotland | Half-breds . . . | 18 | 16 | 0 | 0 | 1 | 1 |
| 23 | Do. | Do. . . . | 20 | 10 | 2 | 10 | 0 | 8 |
| 27 | Do. | Do. . . . | 23 | 19 | 1 | 4·3 | 3 | 0 |
| 29 | Do. | Oxford Down Crosses . | 39 | 23 | 2 | 5·1 | 6 | 8 |
| Feb. | | | | | | | | |
| 3 | Do. | Down Crosses and H.B. | 20 | 16 | 0 | 0 | 4 | 0 |
| 4 | Do. | Half-bred Hoggs . . | 20 | 12 | 0 | 0 | 5 | 3 |
| 6 | Do. | Do. . . . | 19 | 14 | 1 | 5·2 | 1 | 4 |
| 7 | Do. | Down Crosses and H.B. | 20 | 12 | 0 | 0 | 8 | 0 |
| 10 | Do. | Do. | 20 | 8 | 4 | 20 | 4 | 4 |
| 11 | Do. | Down Crosses. . . | 19 | 7 | 8 | 4·2 | 1 | 3 |
| 12 | Do. | Half-breds . . . | 20 | 8 | 6 | 30 | 1 | 5 |
| 12 | Do. | Do. . . . | 20 | 6 | 6 | 30 | 2 | 6 |
| 13 | Do. | Down Crosses. . . | 20 | 6 | 4 | 20 | 4 | 6 |
| 15 | Do. | Half-breds . . . | 20 | 5 | 5 | 25 | 2 | 8 |
| 18 | Do. | Do.. . . . | 20 | 11 | 0 | 0 | 3 | 6 |
| 19 | Do. | Down Crosses and H.B. | 20 | 6 | 8 | 40 | 1 | 5 |
| 21 | Do. | Do. | 20 | 8 | 3 | 15 | 2 | 7 |
| 24 | Do. | Do. | 20 | 2 | 6 | 30 | 5 | 7 |
| 25 | Do. | Down Crosses . . . | 20 | 2 | 10 | 50 | 3 | 5 |
| 27 | Do. | Cheviot Hoggs . . | 20 | 0 | 15 | 75 | 0 | 5 |
| Mar. | | | | | | | | |
| 6 | Do. | Down Crosses. . . | 40 | 9 | 7 | 17·5 | 8 | 16 |
| 12 | Do. | Half-breds . . . | 40 | 7 | 22 | 55 | 1 | 10 |
| 13 | Do. | Down Crosses . . . | 41 | 10 | 13 | 32·5 | 3 | 15 |
| 19 | Do. | Down Crosses and H.B. | 20 | 4 | 7 | 35 | 3 | 6 |
| 25 | Do. | Do. | 40 | 3 | 20 | 50 | 8 | 9 |
| 28 | Do. | Down Crosses. . . | 20 | 4 | 6 | 30 | 2 | 8 |
| 31 | Fife | Do. . . . | 20 | 0 | 16 | 80 | 1 | 3 |
| April | | | | | | | | |
| 1 | S.-E. Scotland | Half-breds . . . | 20 | 5 | 7 | 35 | 0 | 8 |
| 2 | Do. | Do. . . . | 20 | 3 | 10 | 50 | 2 | 5 |
| 8 | Fife | Down Crosses. . . | 19 | 1 | 17 | 85 | 1 | 0 |
| 8 | S.-E. Scotland | Do. . . . | 20 | 5 | 8 | 40 | 3 | 4 |
| 14 | Do. | Do. . . . | 20 | 1 | 12 | 60 | 1 | 6 |
| 15 | Do. | Half-breds . . . | 20 | 8 | 6 | 30 | 2 | 4 |
| 16 | Do | Cheviot Hoggs . . | 20 | 1 | 15 | 75 | 1 | 3 |
| 23 | Do. | Down Crosses. . . | 20 | 12 | 2 | 10 | 1 | 5 |
| 29 | Kelso | Half-bred hoggs . . | 20 | 0 | 17 | 85 | 1 | 2 |

* 30 sarcocysts were found in 10-15 milligrammes

I.

| Total number of times sarcocyst met with. | Percentage number of times met with. | Number of Sarcocysts found in 10-15 milligrammes. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 2 | 11·5 | 2 | .. | .. | .. | .. | . | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 10 | 50 | 10 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 4 | 17·3 | 4 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 16 | 41 | 15 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | . | .. | .. | .. | .. | .. |
| 4 | 20 | 4 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 8 | 40 | 8 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 6 | 31·5 | 5 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 8 | 40 | 6 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 12 | 60 | 10 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 12 | 63 | 10 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 12 | 60 | 9 | 1 | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 14 | 70 | 9 | 3 | .. | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 14 | 70 | 8 | 4 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. |
| 15 | 75 | 8 | 3 | 1 | .. | 2 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 9 | 45 | 7 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 14 | 70 | 11 | 2 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 12 | 60 | 8 | 3 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 18 | 90 | 11 | 2 | 4 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 18 | 90 | 7 | 9 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 20 | 100 | 6 | 7 | 5 | .. | .. | 1 | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 31 | 77·5 | 25 | 4 | 1 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 33 | 82·5 | 9 | 8 | 6 | 4 | 1 | 1 | 1 | 2 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 31 | 75·6 | 15 | 5 | 2 | 5 | 2 | 1 | 0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 16 | 80 | 10 | 3 | .. | 1 | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 37 | 92·5 | 18 | 10 | 4 | 4 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 16 | 80 | 10 | 5 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 20 | 100 | 4 | 4 | 1 | .. | 1 | 2 | 2 | .. | 2 | .. | 1 | 1 | .. | .. | .. | .. | .. | 1 | .. | ..* |
| 15 | 75 | 5 | 8 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 17 | 85 | 8 | 3 | 1 | 4 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 18 | 94·7 | 0 | 2 | 4 | 2 | 3 | .. | .. | 1 | 3 | .. | .. | 3 | .. | .. | .. | .. | .. | .. | .. | .. |
| 15 | 75 | 5 | 5 | 4 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 19 | 95 | 9 | 5 | 1 | .. | .. | .. | 1 | .. | .. | 1 | 1 | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| 12 | 60 | 6 | 2 | 1 | 1 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 19 | 95 | 4 | 2 | 1 | 2 | 3 | 3 | 1 | .. | .. | 1 | .. | .. | 1 | .. | .. | .. | .. | 1 | .. | .. |
| 8 | 40 | 8 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 20 | 100 | 3 | 2 | .. | .. | 5 | 2 | 2 | 2 | 1 | .. | .. | 1 | .. | 1 | .. | .. | .. | .. | .. | 1 |

Number of Sheep in each batch in which Sarcocysts were found.

of muscle in one case in this series.

It will be seen that in all 818 sheep were examined, and the sarcocyst was found, in the sense defined at the beginning of this chapter, present in 553—*i.e.*, in 67·6 per cent. Table II. will show this, as also the number present during each month.

TABLE II.

| | Examined. | Sarcocysts Present in. | Percentage Presence of Sarcocysts. |
|---|---|---|---|
| January . . . | 100 | 32 | 32·0 |
| February . . | 318 | 196 | 61·6 |
| March . . . | 221 | 184 | 83.2 |
| April . . . | 179 | 141 | 78·6 |
| Altogether . | 818 | 553 | 67·6 |

Passing over the actual percentages found, one sees that the percentage number affected increases (with the exception of a slight lowering in April as compared with March, which may be accidental) gradually from January to April. Corresponding with this, one sees from Table III. that the percentage of highly

TABLE III.—PERCENTAGES IN VARIOUS MONTHS OF INFECTED SHEEP HAVING DEFINITE NUMBERS OF PARASITES PER 10-15 MILLIGRAMMES.

| | Number of Sarcocysts found in 10-15 milligrammes. | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 30 |
| Jan. | 96·9 | 3·1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Feb. | 64·7 | 19·3 | 9·6 | 1 | 2·5 | 1 | .. | .. | 0·5 | .. | .. | 0·5 | .. | .. | .. | .. | .. | .. | .. | 0·5 | .. |
| Mar. | 49·7 | 21·3 | 7·6 | 8·1 | 2·1 | 2·1 | 2·1 | 2·1 | 2·1 | .. | 0·5 | 0·5 | .. | .. | .. | .. | .. | 0·5 | .. | .. | 0·5 |
| Apl. | 33·3 | 20·2 | 9·7 | 6·9 | 9 | 4·1 | 2·7 | 2 | 2·7 | 1·3 | 0·6 | 2·7 | 0·6 | 0·6 | 0·6 | .. | .. | 0·6 | .. | 0·6 | .. |

It will be seen from this table that as we advance from January to April the percentage of infected sheep with large numbers of sarcocysts per 10-15 milligrammes becomes greater and greater, while the percentage with small numbers gets correspondingly less.

infected sheep also gradually rises during the same time, and that the percentage with both neck and diaphragm affected shows a similar increase, as Table IV. demonstrates.

TABLE IV.

| | Examined. | Sarcocyst found in Neck and Diaphragm. | Percentage Presence. |
|---|---|---|---|
| January . . | 100 | 5 | 5 |
| February . . | 318 | 76 | 23·9 |
| March . . . | 221 | 91 | 41·1 |
| April . . . | 179 | 94 | 52·5 |

It is interesting also to bring together the batches examined showing the highest percentage of presence of the sarcocyst in both diaphragm and neck with their source. These are shown in the following table:—

TABLE V.

| | Per cent. |
|---|---|
| Kelso batch, 29th April, Half-bred . . . . | 85 |
| Fife „ 8th „ Down Crosses . . | 85 |
| „ „ 31st March, „ . . | 80 |
| S.-E. Scotland batch, 16th April, Cheviots . . | 75 |
| „ „ 27th February, Cheviots . | 75 |

The killing of hoggs ceased about the end of April, and observations were then made on lambs. These observations are summarised in Table VI.

TABLE VI.

| Date. | Breed. | Source. | Number Examined. | Parasites found or not. |
|---|---|---|---|---|
| April 30 | Cheviot | East Lothian | 4 | No parasites found. |
| May 7 | Half-bred | „ | 6 | 4 sarcocysts in 10 mg. of diaphragmatic muscle of one lamb. |
| „ 7 | „ | Mid-Lothian | 7 | None. |
| „ 14 | „ | East Lothian | 20 | 1 sarcocyst in 10 mg. of diaphragmatic muscle of one lamb. |
| „ 24 | Down Crosses | Mid-Lothian | 6 | None. |
| „ 27 | „ | „ | 4 | None. |
| „ 30 | „ | „ | 9 | None. |
| June 3 | „ | East Lothian | 16 | None. |
| „ 5 | „ | „ | 15 | None. |
| „ 5 | „ | Mid-Lothian | 5 | One lamb with 5 sarcocysts in 10 mg. diaphragm. |
| „ 8 | „ | „ | 11 | None. |
| „ 11 | Half-bred | East Lothian | 10 | One lamb with 1 sarcocyst in 10 mg. neck muscle. |
| „ 11 | Down Crosses | Mid-Lothian | 8 | None. |

Thus 121 lambs, born in February, were examined in the usual way during May and early part of June. Sarcocysts were found in four, or 3·3 per cent. In one case the parasite was found in considerable numbers at an age of from three to four months. The fact, however, of the comparative absence of the parasite at this early age should be taken into account along with the fact shown especially in Table IV.—namely, that even over a space of three months a noticeable increase in the number of parasites is observable. This has an important bearing, as will be seen later, on the question of the relation of the sarcocyst to the disease scrapie.

Mutton obtained from ewes over the scrapie age (two years) was next examined for the presence of sarcocysts. These varied in age from three to six years. They were killed in the Edinburgh slaughter-house, and it is more than likely that some of the lots, though not all, were the remains of scrapie-infected flocks. Indeed, Mr Henderson, M.R.C.V.S., who obtained the specimens for me, was at a loss to explain why such apparently good breeding ewes were being killed unless it were for some such reason. Instructions were given that samples should be taken only from *fat* sheep. By this means it was hoped to some extent, but not entirely, to exclude scrapie animals. The results of this examination are given in Table VII. (p. 99).

The points brought out in this table are that in sheep above the scrapie age, and apparently in good health as evidenced by the fat condition in which they were killed, sarcocysts are present in much smaller numbers than in fat hoggs less than a year old derived from the scrapie area (*vide* Table I.), and that in these healthy sheep the sarcocysts are present in very small numbers as compared with their presence in scrapie sheep (*vide* Chap. III., where a scrapie sheep had 150 sarcocysts per 10 milligrammes).

Through the kindness of one farmer, facilities were given to follow to the slaughter-house a batch of three-year-old ewes, the remains of a pack from which a considerable number had died of scrapie. These animals were not examined by me during life, but were said to be fat and in good condition.

## TABLE VII.

| Date. | Breed. | Number of Sheep examined. | Sarcocyst not found in. | Sarcocyst found in both neck and diaphragm. | Percentage. | Sarcocyst found in neck alone. | Sarcocyst found in diaphragm alone. | Total number of times Sarcocyst met with. | Percentage number of times met with. | Number of Sarcocysts found in 10-15 milligrammes. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1913. | | | | | | | | | | | | | | | | | | | | | |
| Nov. 4 | Cheviot ewes 4-5 years | 16 | 9 | 3 | 18 | 2 | 2 | 7 | 43·7 | 4 | 1 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| ,, 16 | Cheviot ewes 4-5 years | 21 | 7 | 8 | 38 | 3 | 3 | 14 | 66 | 10 | 4 | 0 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| ,, 19 | Cheviot ewes 3-4 years | 21 | 7 | 8 | 38 | 3 | 3 | 14 | 66 | 9 | 3 | 0 | 1 | 1 | .. | .. | .. | .. | .. | . | .. |
| ,, 26 | Cheviot ewes 3-4 years | 19 | 2 | 14 | 73 | 2 | 1 | 17 | 89 | 3 | 3 | 4 | 1 | 1 | 1 | 1 | 2 | .. | .. | .. | 1 |
| ,, 28 | Cheviot ewes 3-4 years | 16 | 6 | 3 | 18 | 2 | 5 | 10 | 62 | 3 | 2 | 4 | 1 | .. | .. | .. | .. | .. | .. | .. | .. |
| Dec. 8 | Cheviot ewes 3-4 years | 16 | 3 | 8 | 50 | 1 | 4 | 13 | 81 | 9 | 3 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| ,, 11 | Blackfaced 4-5 years | 22 | 12 | 4 | 18 | 4 | 2 | 10 | 45 | 8 | 0 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1914. | | | | | | | | | | | | | | | | | | | | | |
| Jan. 17 | Cheviot ewes 3-4 years | 19 | 4 | 8 | 42 | 1 | 6 | 15 | 78 | 12 | 2 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. |
| Feb. 25 | Cheviot ewes 3-4 years | 20 | 8 | 5 | 25 | 5 | 2 | 12 | 60 | 8 | 2 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. |

Number of Sheep in each batch in which Sarcocysts were found.

Specimens were obtained from only four of them, and the result of their examination is given in Table VIII.

TABLE VIII.

| | Neck Muscle. | Diaphragm. |
|---|---|---|
| Sheep 1. | 0 | 1 |
| „ 2. | 2 | 0 |
| „ 3. | 0 | 1 |
| „ 4. | 15 | 3 |

Unfortunately the ewes examined are too few for any conclusions to be drawn.

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# CHAPTER XI.

## EPIZOOTIOLOGY.

For statements with regard to the epizootiology of the disease one is dependent on the farmers and shepherds in the area affected. Doubtless many of the statements made by them are accurate; but, on the other hand, several circumstances unite to cause a large number of such statements, and more especially the popular deductions from them, to be untrustworthy, though unintentionally so. The disease is a very fatal one to the sheep: and popularly it is one of the most widespread rumours about the disease that it is transmitted to the offspring. The direct loss in the one case, and the indirect one in the other through the depreciation in value as a breeding stock for sale has caused a *suppressio* at least, if not a *perversio veri*. The farmers with the disease among their stock with whom one can freely discuss it, though becoming more numerous, are still very few.

Faulty power of observation, again, is responsible for several of the patent inaccuracies of the popular view about the disease; while false analogies, as that of this disease with human syphilis, the passing on and amplification of hearsay rumours, and the confusion of deductions from supposed facts with facts themselves, have tended to make this aspect of the subject very chaotic. The result is that the onlooker, if he attempts to gain an insight into the disease by this method, can do no more than balance probabilities. And this is more or less what is done here; statements, however, being rejected as evidence, which are on the face of them inaccurate.

To commence, then, there would appear to be unanimity both in this country and in other countries with regard to the disease being hereditary, or, as it is better put, congenitally infectious. Scrapie ewes almost invariably produce lambs which sooner or later develop scrapie. This is one of the best-established epi-

zootiological facts about the disease, and so far as my experience goes in listening to the statements made by farmers, is warranted. When, however, the question is raised as to whether it is infectious as well as hereditary, or whether the disease is transmitted by the rams or by the ewes, great variation of opinion arises. As regards the contagiousness of the disease, up to the present, there is no evidence of such a condition existing. Had it existed, with the sale broadcast of lambs from scrapie flocks, and of such ewes from the flocks as had survived till they were of age to be cast, the disease would now be widely spread. Such, however, is not the case. Again, the usual method of combating the disease, consisting in selling off the old ewes and buying in young sheep from clean flocks, renders such a view untenable; for here the diseased and healthy mingle freely with one another; and yet when the last of the diseased stock has been sold the disease has been stamped out. This has been the experience of several farmers with whom I have discussed the matter personally. Such a condition of affairs, again, negatives the idea that the infection hangs about a place, on the pasture, fences, &c. One view of the infection which I have heard canvassed is that it is "on the ground," and the lambs pick it up. Lambs are specially noted because of the appearance of the disease at two to two and a half years. Possible heredity has been in the minds of those holding this view. Here again, however, the facts do not fit in with such a view, for there is no reason why, if such were the case, the lambs from scrapie mothers should be highly affected out of all proportion to the lambs from apparently healthy mothers, going on the same pasture, as my own observations on this subject show. We have already seen that a lamb born from a scrapie ewe will develop the disease, even if it is taken away at once from the mother and put on to a healthy sheep. Indeed this is the usual method of rearing the produce of scrapie ewes; and the instances of the occurrence mentioned are legion. While all the evidence, therefore, points to the non-contagiousness of the disease, for the sake of completeness let us examine an imaginary case where the disease appeared in a flock subsequent to the introduction into that flock of some diseased stock. Two points must be considered very carefully before the conclusion is arrived at that the diseased animals

infected the healthy by contagion. Careful inquiry must be made to determine that the disease was not present in a sporadic form unrecognised, to be afterwards maintained and spread by hereditary factors, in the supposed healthy flock, prior to the introduction to it of the diseased sheep. The arrival of the diseased sheep in some number, at a time when attention was focussed on the subject by public discussion, might sharpen the diagnostic powers of the owner. Such a condition of affairs is not hypothetical, for I know of the case of a farmer in Roxburgh, farming in the midst of the disease, who had scrapie on his farm and did not know he had got it. On the other hand, the question of the origin of the disease among the healthy sheep *de novo*, following on a certain system of breeding, the possibility of which I shall afterwards discuss, has to be kept in mind, and its likelihood excluded before opinions as to the contagiousness of the disease are expressed.

Many statements are current about the passing on of the disease by the tup. In all the cases I have inquired into, where this has been alleged to have taken place, the state of matters has been somewhat as follows. Scrapie has appeared in a flock, and the owner, casting about for a reason, and as he can find no other, blames a tup which he has got from such and such a place (cf. German case *supra*). When asked, however, whether the tup in question had scrapie, or eventually developed it, invariably his answer has been in the negative. Further, no cognisance has apparently been taken of the facts that the disease may quite as well be passed on by the ewe side; and that if the tup spread the disease, instead of one or two cases occurring in the beginnings of the disease in a flock, almost every ewe tupped by that ram ought to produce a scrapie lamb. Much confusion has been introduced into the subject by farmers tracing a resemblance between this disease and their conception of what human syphilis is. One even hears it stated that the tup passes on the disease to the ewe. There is no evidence, however, for such an occurrence: and personally I know of several cases where a tup has died of scrapie after serving the ewes, and none of the ewes tupped by him or of his progeny after the lapse of a sufficient time have shown evidence of the disease.

On any hypothesis of venereal infection it would seem impossible to explain such authentic cases as the following—

viz., an apparently healthy tup and apparently healthy ewe giving rise to a "scrapie" lamb; and to a less extent a scrapie mother giving rise to a healthy lamb. Such cases do occur, and, taken together with the fact that a scrapie tup would appear not to infect his progeny are circumstances which to my mind cannot be explained on any known theory of sexual infection or even mixture of such theories.

It may further be emphasised that were the tup the means of spreading the disease, it is not overstating the case when one says that, taking into consideration the fact that Northumberland and Roxburgh up till lately supplied a large part of Scotland with tups, a great number of flocks all over Scotland would be infected. This state of affairs is far from being the case, as the disease is authentically known up to the present to exist only in the two counties mentioned.

In-breeding and the breeding of high-class stock have been alleged as the causes of the disease. While not actually causing the disease, it would appear that these have a powerful influence in determining it; for these conditions lead to, firstly, a non-introduction of fresh blood and a keeping up, possibly in an ever increasing extent, of any taint once introduced; and secondly, the tendency to keep alive any animal, no matter what its heredity or what its condition, provided it has "show" points.

As regards the breeds affected by the disease, while all are agreed that the Cheviot, the Leicester-Cheviot, and especially the progeny of the Leicester-Cheviot ram with the Leicester-Cheviot ewe are affected, there is not the same assurance with regard to other breeds, possibly because the disease does not affect them to the same extent. That it does occur in other breeds such as the Blackface, and the pure Border Leicester (*vide supra*) cannot be doubted, and it is a historical fact that in this country during the latter part of the eighteenth century it occurred in almost all the English breeds (*vide supra*). In Germany it occurs in the Merinos chiefly, but cases have also been recorded in the South Down.

With regard to its occurrence in the sexes, several popular opinions are held more or less strongly. For instance, one common statement is that it occurs principally in tups. As regards the accuracy of this, I may state that while it was

easy in my investigations to obtain specimens of ewes with the disease, I had the greatest difficulty in getting a tup. Apart from this, tups are numerically much fewer in number than ewes, and a case among the tups on a farm bulks much larger in the perspective than even fifty cases amongst the ewes would do, for the proportion of tups to ewes runs about 1 in 50. Again, it has been asserted with confidence by some that wethers and eild sheep are less affected than the others. With regard to the wethers, practically no wethers exist nowadays at the dangerous age for the appearance of scrapie, all having been killed for mutton at one year old, and eild ewes are few in number and are at once fattened off.

Views are current, too, with regard to the season of the year at which the disease is most prevalent. Little reliance can be placed on these at this stage, but the general opinion at present is that it is most prevalent in spring. It would also seem as if the appearance of the symptons of the disease had some relation to pregnancy. This statement must not be construed as meaning that pregnancy is *necessary* for the appearance of the disease, as is held by some, for cases occur in tups, wethers, and eild ewes. All it means is that pregnancy may have a favouring influence on the development of the disease.

Varied opinions, too, are held with regard to the duration of the disease once it has begun in an animal. Seeing that a diseased animal, almost without exception, is killed as soon as the condition is observed, few statistics are available for deciding this question. I have seen a case, which was fairly advanced when I obtained it, live for at least five months. In most cases the animals die from some intercurrent affection; and such, one would suppose, would be more frequent in the winter season. The summer season one might with justice suppose, owing to its heat, would aggravate the itchiness. Whatever is actually the state of matters, it has been held by some that cases last longest in summer, and by others equally confidently that the duration is more prolonged in winter. No attempt is made here to say which is correct.

Authentic cases are on record where a scrapie lamb was produced from parents which never developed scrapie. I know of an actual instance where this was the case, and such

occurrences must be happening in every flock, for no one willingly breeds from obviously infected animals. The obverse of this statement is true also, for a scrapie mother may give rise to a healthy lamb.

As regards the age at which the disease occurs most frequently, opinion is unanimous that it is round about two years of age. Cases may occur earlier than this, and also above this age, even up to five and six years, but they are few comparatively speaking, and get rarer as one gets more remote from the time of maximum occurrence. In some of the infectious fevers of short duration one may, even though not knowing the nature of the disease, relegate with some degree of accuracy a series of cases cropping up at the same time, with the same symptoms, to the same source of infection. Notable instances of this occur—*e.g.*, in connection with the tracing of scarlet fever epidemics to milk supplies; and of epidemics of typhoid, cholera, &c., to water supplies. Were the disease contagious there is no reason why the cases should be grouped around the one age period. From this fact and from the other epizootiological facts available one could almost state, without having recourse to a consideration of the pathology of the condition, that infection took place almost certainly before birth while the lamb was still in the uterus.

As regards the method of origin of the disease in a flock, apart from cases where the disease has been introduced by a draft of infected ewes, the usual history one gets is that the disease began with a case or two, and from that time onwards spread until a large number of the flock were affected. Such a course is in favour of what I shall describe later as the apparently *de novo* origin of the disease, and would appear to be incompatible with the introduction of the disease by a tup, where one would naturally expect a large proportion of his offspring to be affected with the disease.

Another point that one would like to draw attention to here is the current belief in the district affected, that high feeding instead of mitigating the disease tends to bring it out more. In this connection it is even stated that the disease takes a year longer to develop among the Cheviots on the East Border, with their comparatively poor feed, than with the half-breds and Cheviots on the heavy arable ground in Roxburghshire.

It is interesting, too, to note that this same belief was held in England during the latter half of the eighteenth century (*vide supra*, Chapter I.).

Very little need be said here about the symptoms, as it would be in the main a repetition of what has been said in a previous chapter. The all-important thing in the diagnosis of the disease at all times is the itchiness. It is the hall-mark of the disease, and is the earliest sign by which one may recognise it. Cases, however, may exist with this symptom absent. The loss of wool on head, sides, and rump; the change in colour of the wool, sometimes blue and dead, at other times brownish, giving an appearance of thriving to the animal, but due to rubbing against earthy banks; the restlessness; the excoriations on the nose, legs, &c., are all evidences of it. Later, emaciation and muscular weakness set in to complete the picture. The appetite is maintained and diarrhœa is absent.

An important point is the diagnosis of this condition from the condition called *pining*.[1] The absence of the itchiness and restlessness; the presence of diarrhœa; of "poking" beneath the jaw; the "divot"-like feel of the wool; and the fact that, if taken in time, the piner can be "cured" for the time being,—all serve to differentiate this condition from scrapie. In the Appendix will be given some observations on a typical "piner" of this class, and there it will be seen that in it the same pathological condition, and apparently the same pathogenic organism as obtains in Johne's disease of the cow, were found.

Neither from my own observations nor from information supplied by others am I able to say whether a tup actually suffering from scrapie is able to procreate, or a ewe in a similar condition to have rut and conceive. It is certain, however, that it is with difficulty that a scrapie mother nurses her lamb. Usually she is not allowed to do so, but where she has been given the chance, in most cases she has been unable to do so. Much, however, obviously depends on the stage of the disease which the animal has reached.

The treatment of the epizootiology of the disease given in

[1] The term "pining" sheep, or "piners," is possibly applied by farmers and shepherds in different localities to animals affected with very different diseases. Here, however, the term is restricted to the disease described below,—a disease which occurs in the same localities as scrapie, and is locally known by this name.

this chapter may not have been exhaustive, but sufficient has been said to enable us to select one or two statements about it and its spread which one may regard as being more or less probably true. Thus, for instance, speaking epizootiologically, one may say that probably the disease is congenitally infectious, and that it is passed from the mother to the lamb in the uterus; that the mother alone spreads the disease; that the tups do not; that the disease is not contagious; that a healthy ewe may give rise to a scrapie lamb; and a scrapie ewe to a healthy lamb; and that to explain the origin of the disease in certain flocks necessity compels us to assume a *de novo* origin of the disease as there is no other possible origin feasible. Is there, then, any one theory that would account for all the facts? *The existence of a certain infection among the ewes, transmissible to the offspring by congenital infection, harmless in the great majority of cases, but capable of concentration, and consequent harmful action by the special method of breeding to be afterwards mentioned, would appear to satisfy such a demand.*[1]

In the presence of sarcosporidiosis we have the required infection, and it would not be surprising (*vide* my statistics above) if all the sheep in Scotland were infected with this parasite, and in many cases without apparent injury. As my own experiments have shown, sarcosporidiosis is passed from mother to lamb in the uterus. The type of breeding which has tended to concentrate and highly infect sheep is the one where *the ewe stock* is kept up by breeding the ewe lambs from the gimmers—*i.e.*, *from the two-year-old ewes, at the age when scrapie or, in other words, heavy sarcosporidial development, is most rife.* The heavily-infected mother will produce a heavily-infected lamb, and so, until the method of breeding is corrected, the process will go on to extermination of the flock, as has occurred in many cases. The real determinant for the disease would appear to be this method of breeding, and given a healthy stock—*i.e.*, a stock with very light sarcosporidial infection—to begin with, and the operation of this method of breeding, then after a few years, automatically, or, as one might say, "*de*

[1] It is interesting to note that one of the methods for combating the disease advocated in Germany and France (*vide supra*) is to avoid using tups till they are over two years old. Independently this method has been employed by one farmer, personally known to me in Roxburghshire, who for some years past has been using nothing but the oldest tups he could get.

*novo*," heavy sarcosporidial infections develop and scrapie appears. After the dangerous age has passed, all the ewes heavily *infected* and liable to infect heavily their progeny with sarcosporidiosis will, however, have died out; and it is questionable whether, if this method of breeding from the gimmers had not been employed, the disease scrapie could ever have arisen in endemic proportions. In other parts of Scotland, indeed, where the practice is to keep up the ewe stock by *drawing* the *best* ewe lambs from *all* the ages the disease has not appeared. Where this is done for one gimmer's lamb drawn for breeding, there are usually five or more drawn from the ewes of the older ages—that is, from the ages which in all probability are free from heavy sarcosporidial infection. The arising of a scrapie case from healthy parents is only a particular case of the "*de novo*" method of origin, and the existence of a healthy sheep born from a scrapie mother is rare, and similar cases occur in other infectious conditions. The appearance of the symptoms at two years is explicable on the ground of the time required for a dangerous multiplication of the parasite to take place. The cause of the lethality of the condition and the hopelessness of cure are evident if the condition is one of heavy sarcosporidial infection, with its seat deep in the muscles and consequently inaccessible.

The capability of heavy sarcosporidial infection explaining other aspects of the disease is treated in other parts of this investigation, and it is unnecessary to repeat it here.

# CHAPTER XII.

## CONCLUSIONS AND RECOMMENDATIONS.

I PROPOSE here to state briefly the conclusions I have arrived at in connection with this investigation, and to give a possible method of dealing with the disease.

In the first place, I believe scrapie to be caused by a *heavy infection* of the sheep with a protozoan parasite (sarcosporidium). This heavy infection would appear to be brought about by the system of breeding in vogue in the regions where scrapie is in evidence—namely, the keeping up of the ewe stock by means of the ewe lambs derived from the gimmers (two-year-old ewes). This is the age period at which scrapie (or heavy sarcosporidial development in the animal) occurs most abundantly, and these heavily-infected mothers pass on a heavy infection to their progeny.

I have obtained *no* evidence, epizootiological or pathological, that the disease is spread by the ram.

I am led to take the position that scrapie is due to a heavy infection with sarcosporidia from the following among other considerations:—

1. The sarcocyst is always present in the skeletal muscles of scrapie sheep in large numbers; and the more advanced the case the larger is the number of the sarcocyst present.
2. Pruritus (or itching), the chief symptom in scrapie, can be reproduced in rabbits by the injection into them of sarcosporidial emulsions.
3. Careful clinical examination of typical cases makes it highly probable that the paretic phenomena of the disease are due to a primary muscle lesion.
4. There is an absence of any condition post-mortem, except extensive sarcosporidiosis, sufficient to or

of a nature likely to cause the phenomena observed in the disease. In this connection one would specially note Cassirer's findings in cases of the Traberkrankheit in Germany (*vide supra*).

5. No single view can explain so well the symptomatology and epizootiology, &c., of the disease as this.

It might be well to draw attention, without summarising, to some of the other important points touched on in this investigation. Some statistics, for instance, are given in chapter x. relative to the presence of sarcosporidia in sheep of different kinds in Scotland. The pharmacology of sarcocystin and its relation to other animal poisons and to the production of the symptoms of scrapie is discussed in chapter vii.; while in chapters v., viii., and ix. some possible developmental stages of the sarcocyst, and the method of spread of sarcosporidiosis are dealt with. For detailed discussion of such points the original chapters should be consulted.

As regards recommendations for dealing with the disease these can be put forward very briefly. Treatment would appear to be useless, and the affected animal should be sent to the butcher at once before the sarcocysts have become very numerous and the animal emaciated.

Entirely changing the stock by bringing in fresh young ewes from clean flocks and gradually getting rid of the old is an efficient if expensive way of getting rid of the disease. It should, however, always be undertaken where the flock is heavily infected.

From my own investigations, I should recommend that the ewe stock should be kept up from the progeny of the older ages of ewes, and that the progeny of the gimmers, and possibly of the two crop ewes, should be sent to the butcher.

Diseased animals should at once be killed to prevent any possibility of their being used as breeding stock; while for the reasons stated above (page 104), in-breeding should be conducted with very great caution.

# APPENDIX.

Stockman (Annual Report of Chief Veterinary Officer for 1909, 'Journal of Compar. Path. and Therapeutics,' vol. xxiv., 1911, p. 66), while investigating "scrapie," described cases of what he considered to be Johne's disease in the sheep. Beyond, however, stating that the animals purged severely, nothing is said regarding the symptoms in these cases.

Twort and Ingram ('A Monograph on Johne's Disease, 1913') mention (p. 12) that Vukovic found cases of the disease among mountain sheep in Bosnia; that M'Fadyean, Sheather, and Edwards had a case in a Welsh ewe; and that they themselves had examined the intestines from a case of the disease in Northamptonshire. Little or nothing, however, is said regarding the epizootiology and symptomatology, &c., of the disease as it occurs in sheep in these communications, and for this reason my observations on this subject may be worthy of record.

On two farms at least in the Border district during my investigation into scrapie I have met with a disease called by the shepherds "Pining," and characterised by the following symptoms, &c. It generally shows itself in the months of October, November, and December in second-crop ewes. Younger ewes would appear not to be affected to the same degree. It begins by a slight falling off in condition, with diarrhœa, which, however, is not a continuous symptom of the disease, but is intermittent, stopping for several weeks at a time only to break out again. The eyes show a distinctly yellowish tinge in the white. The wool is of a dirty blackish colour, as if the animal has been in the vicinity of smoky chimneys, and the slightest pull brings it away. The animal gets gradually weaker and thinner, although it may go on feeding till practically the end, which may come at any time from six to eighteen months after the onset. The animal may give birth to and rear lambs meanwhile. "Poking" under the jaw appears late in the disease and may come and go: it is, however, a sign of approaching death. It would appear that abnormal thirst is present in some of these cases. A temporary improvement is sometimes observed: no treat-

ment as yet employed seems to effect a permanent cure, although putting the animal on good young grass in the spring causes a marked change for the better in some cases. Such symptoms, it will be observed, are practically those of Johne's disease as it occurs in cattle.

The disease is not alarming from the standpoint of the numbers attacked; but from four or five to a dozen, varying with the number of sheep kept, are quite commonly attacked in the year.

One of these cases was examined by me during life and after death. She was a two-year-old half-bred ewe which had been bought in as a lamb. She was first noticed to be falling off in condition, and to have diarrhœa at the beginning of January 1914 when she went on to the turnips. When seen at the end of March she had the appearances described above. There was "poking" under the jaw which had appeared a month previously.

She was killed and "post-mortem" was found to be very lean and emaciated. Otherwise, with the exception of a few worm patches in the lungs, the organs and tissues appeared to be healthy to the naked eye. There were no flukes in the liver. In the alimentary tract, no strongyles were found in the fourth stomach, and only two or three sclerostomes in the small intestine. A single small tape-worm was found in the colon. In the small intestine towards its lower end three patches, each about a foot long, of great thickening of the walls, were found. The thickening extended cylindrically round the gut. Examined from the inside, the surface was not wrinkled, but was covered with a greyish-yellow membrane. Smears made from this showed the presence of acid-fast bacilli in large numbers. Fig. 26 shows a group of these towards the lumen of the gut in a section through its walls; acid-fast bacilli were also found in smears from the mediastinal glands. This was the only pathological change of importance noted, and the case would appear, therefore, to be one of Johne's disease. Strongyle and sclerostome infection are commonly said to be the cause of "pining," but the presence of both even in large quantities in apparently healthy sheep, and the absence of one and practical absence of the other in the above case, would seem to be against this view. The possibility, therefore, of a large number of the so-called "piners" of the Border district being actually Johne's disease cannot be overlooked; and if this is established as a fact, the necessity of at once destroying "piners" to prevent infection of other members of the flock is obvious.

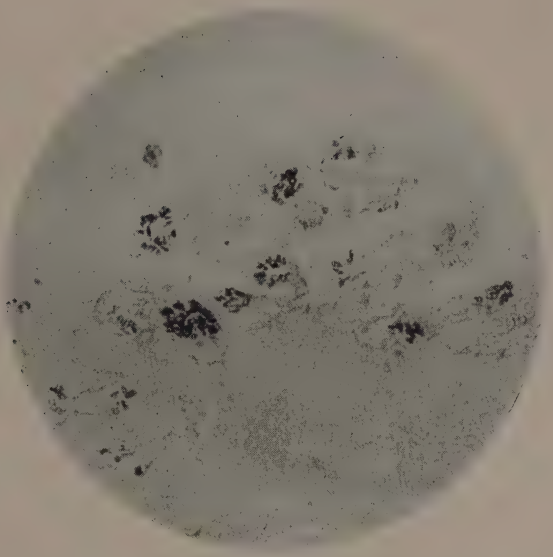

Fig. 26.—Section of patch in small intestine of this sheep, showing the acid-fast bacilli (Johne's) in the necrotic material covering the surface of the gut. A large number of them are inside cells.

# GLOSSARY.

**Adnexa,** neighbouring structures.
**Ætiology,** investigation into causes.
**Aerobic,** growing in the presence of air.
**Amœba,** a group of lowly animal forms which consist of a single cell.
**Anaerobic,** growing in the absence of air.
**Anaplasmata,** small bodies in the red blood cells, nature unknown.
**Anaphylaxis,** the condition of being more susceptible to the administration of some substance.
**Antibodies,** substances formed in the animal body for neutralising foreign materials.
**Ascites,** an effusion of fluid into the abdominal cavity.
**Asphyxia,** want of aeration of the blood, usually due to deficient supply of air to the lungs.
**Ataxia,** unsteadiness.
**Atrophy,** wasting.
**Cachexia,** a state of wasting, emaciation, debility, usually after a prolonged illness.
**Cerebellum,** the lesser brain.
**Chromatin,** a substance in body cells which has affinity for certain dyes.
**Chromaffin,** a substance occurring in the suprarenal gland which stains in a special way.
**Ectozoa,** external parasites.
**Ecto-parasites,** external parasites.
**Enzyme,** a ferment.
**Enzootic,** existing among animals in a certain region.
**Encapsulation,** surrounded by capsule or covering.
**Endogenous spread,** spread from place to place inside the animal.
**Eosinophilia,** an increase of certain of the white cells of the blood.
**Epizootiology,** dealing with the spread of the disease among animals.
**Epithelial cells,** cells covering a body surface.
**Excoriations,** abrasions, ulcers.
**Exogenous spread,** spread outside the animal body, from animal to animal.
**Extrinsic,** indirect.
**Falciform,** sickle-shaped.
**Farriery,** veterinary practice by a farrier.
**Filaria,** a small worm-like parasite, here existing in the lungs of the sheep.
**Filariasis,** the condition due to Filaria.
**Filtrable,** capable of passing through a filter of special pore diameter.
**Ganglia,** collection of special nerve cells.
**Glottis,** entrance to windpipe.
**Gluteal,** hip region.
**Hæmolysis,** solution or "laking" of red blood corpuscles.
**Histology,** appearances of tissues when examined under high magnification.
**Hyaline,** refractile, clear, hard, transparent.

**Ileum**, part of the small intestine.
**Jejunum**, part of the small intestine.
**Lipoid**, a variety of fat.
**Lumbar**, in the region of the loin.
**Lumen**, cavity.
**Microscopic**, as examined under the microscope.
**Micturition**, passing water or urinating.
**Musculature**, a collective term for the muscles of the body.
**Myocardium**, muscle of the heart.
**Œdema**, dropsy.
**Œsophagus**, gullet.
**Omentum**, a membrane hanging down from the stomach usually filled with fat, the "apron."
**Paraplegia**, paralysis of the lower part of the trunk and the legs.
**Parenchymatous**, affecting the special and specific tissue of an organ.
**Paresis**, a weakness of the muscles, not amounting to actual paralysis.
**Pathogenicity**, capacity of producing disease.
**Patellar reflex**, a reaction in connection with the muscles actuating the knee joint.
**Pectorals**, set of muscles on outside of chest.
**Peristalsis**, the worm-like movements of the intestine during life.
**Peripheral**, opposed to central; dealing with the surfaces and extremities of the body.
**Perirenal**, surrounding the kidney.
**Peridural**, surrounding the covering of the spinal cord.
**Pericardium**, heart bag.
**Pleura**, covering of the lungs.
**Polychromasia**, the taking on of several shades of colour.
**Prophylaxis**, rendering less susceptible to disease.
**Pruritus**, itching.
**Psoas**, a muscle passing from the loin to the thigh.
**Sclerostome**, a thread-worm parasite of intestines.
**Skeletal**, attached to the skeleton.
**Sternomastoid**, a muscle of the neck.
**Strongyle**, a thread-worm parasite.
**Striation**, striping.
**Subcutaneous**, beneath the skin.
**Suprarenals**, two glands at the upper end of the kidneys in the abdomen.
**Symptomatology**, dealing with the symptoms.
**Teleological**, intentional, purposive.
**Thyroid**, a gland in front of the windpipe.
**Thermolabile**, destroyed by heat of a certain degree.
**Toxin**, poison.
**Trachea**, windpipe.
**Trichinosis**, affected with the Trichina spiralis, a thread-worm whose embryo lives inside the muscle fibres.
**Vacuolation**, system of holes or pores.
**Venin**, a poison (chiefly applied to snake poison).